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September 1987

**A  
COMPENDIUM OF  
TECHNOLOGIES  
USED IN THE TREATMENT  
OF  
HAZARDOUS WASTES**

Center for Environmental Research Information  
Office of Research and Development  
U.S. Environmental Protection Agency  
Cincinnati, OH 45268



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## **DISCLAIMER**

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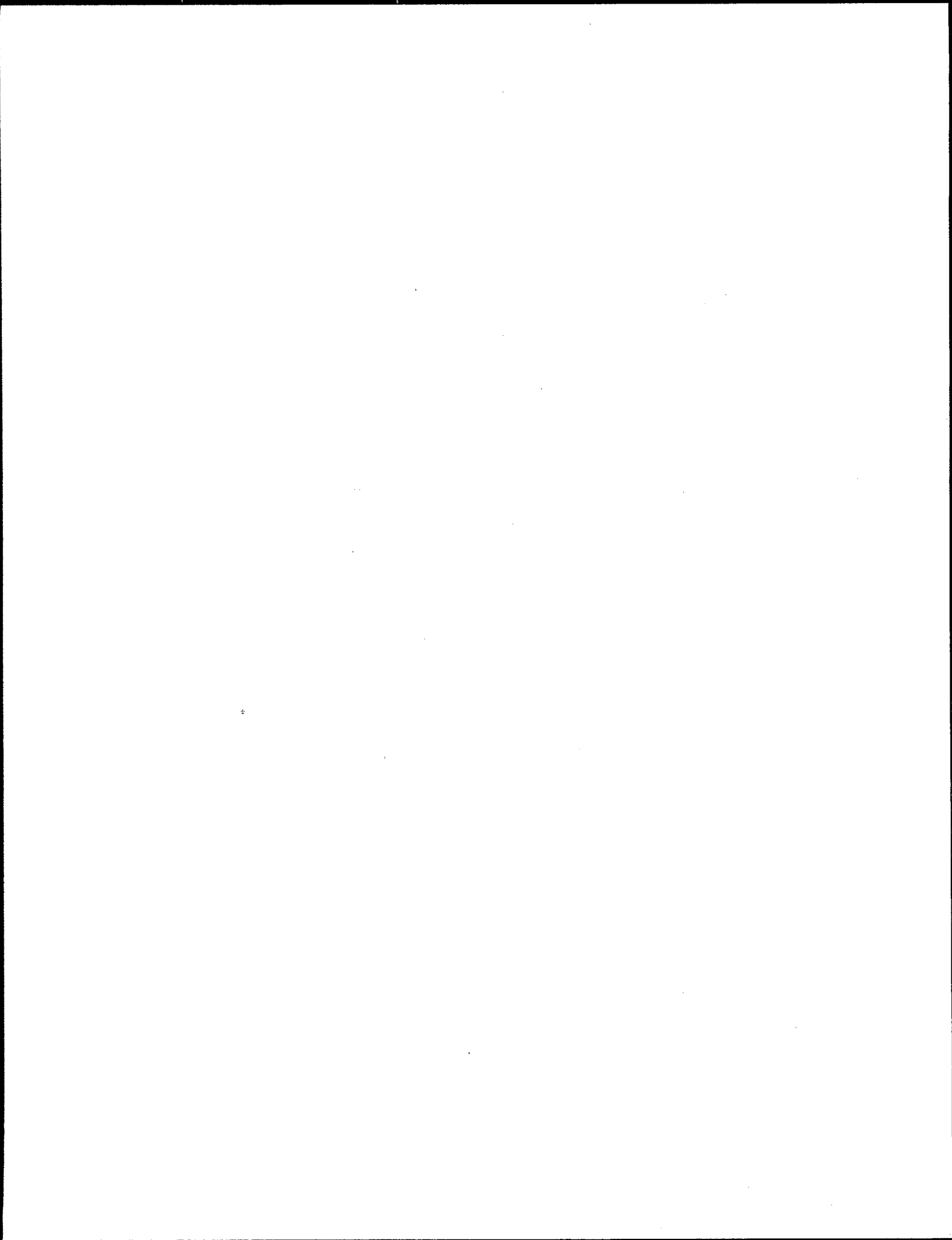
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## **ACKNOWLEDGEMENT**

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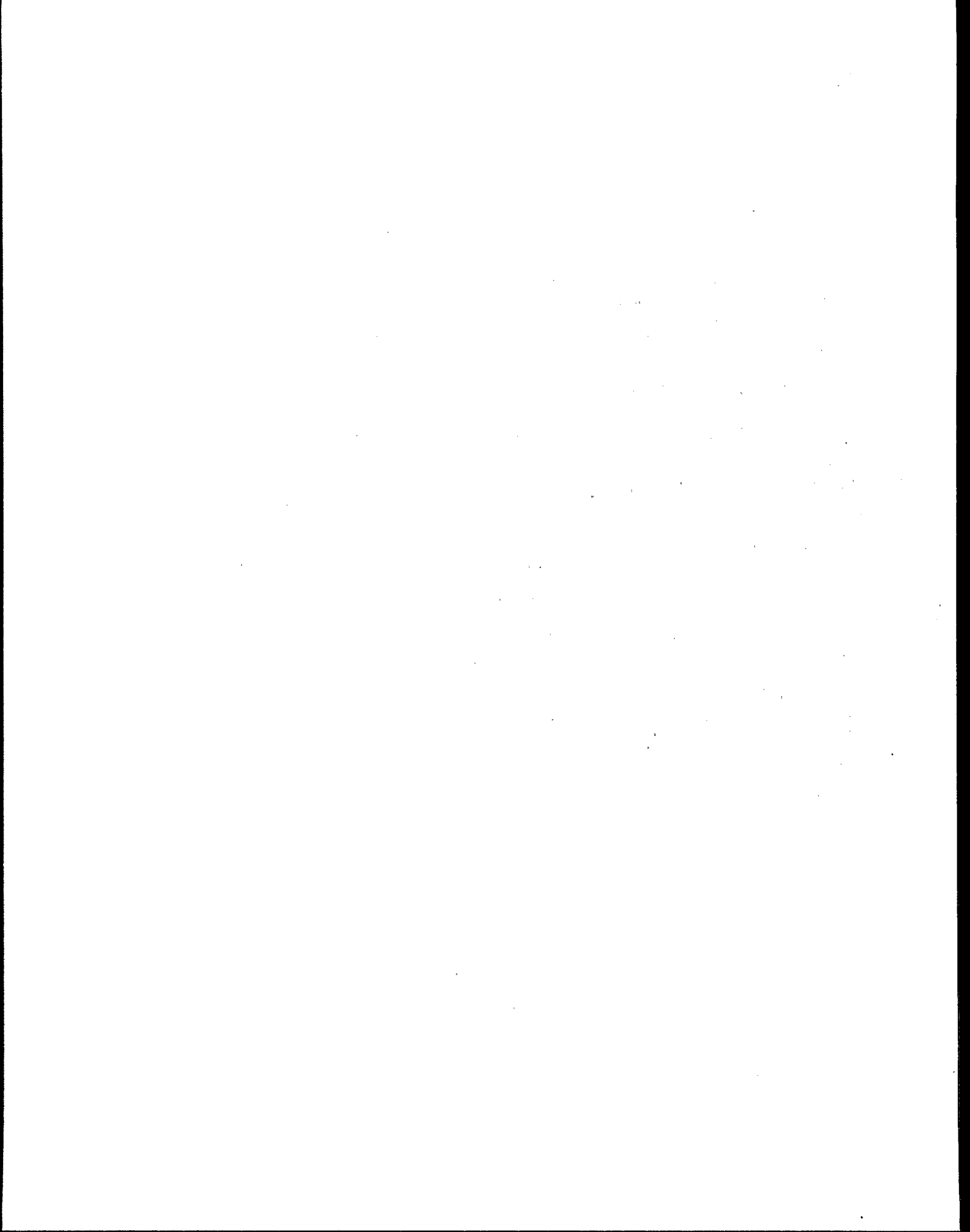
## FOREWORD

This document is intended to serve as an introduction to available technologies which can be used in the treatment of hazardous wastes. In the context of this document, hazardous wastes include RCRA-regulated wastes, such as would come from a generator or storage facility, as well as those wastes which have contaminated some other medium, such as soil or groundwater, and thus, would be considered "CERCLA wastes." It should be noted that no one of the waste treatment technologies presented is a stand-alone process. Any treatment scenario utilized for hazardous waste must include a process line made up of several of the treatment processes discussed herein.

While the contents of this document are not exhaustive, it is believed that most treatment processes available now and in the near future are discussed. Each technology discussion includes a description of the basis of the technology, a brief discussion of the applicability and limitations of that technology, the status of the technology, a non-exhaustive listing of sources (vendors, suppliers or developers) of the technology and when appropriate, a process diagram for a typical application of that technology. Furthermore, for many of the technologies, a tabular listing of specific data needed by an engineer designing a treatment system is included.

Technologies are categorized on the basis of whether they are considered physical treatment, chemical treatment, biological treatment, thermal treatment (incineration) or stabilization/fixation. Obviously, there is overlap in the minds of many regarding the categorization of the different technologies. For example, some people consider UV photolysis to be a physical process because of the necessity for ultraviolet irradiation while others merely consider it hydrolysis wherein the activation energy is supplied by the UV irradiation. In this document the latter view is taken. Similarly, the fixation/stabilization processes are all either physical or chemical processes. However, the purpose for their use, the design factors for consideration and the requirements on their end product are so unique that it is felt that these processes deserved separate treatment.

The source list for each technology is admittedly incomplete. The list is not intended in any way to endorse the vendors on the list, nor is it a commentary on any capabilities of vendors not listed. The list is supplied partly as a convenience to the reader, but primarily as an indicator of the overall availability of that type of technology. In the case where the number of known vendors is exceedingly large the reader is referred to other sources such as annual buyer's guides published in trade and professional journals.





## PHYSICAL TREATMENT PROCESSES

The processes described herein are those which utilize physical characteristics to effect a separation or concentration of constituents in a waste stream. The processes are organized into four groupings according to their physical basis, i.e., separation by gravity, separation by phase change, separation by dissolution and separation by size, adsorptivity, or ionic characteristics.

### Gravity Separation:

- Sedimentation
- Centrifugation
- Flocculation
- Oil/Water Separation
- Dissolved Air Flotation
- Heavy Media Separation

### Phase Change:

- Evaporation
- Air Stripping
- Steam Stripping
- Distillation

### Dissolution:

- Soil Washing/Flushing
- Chelation
- Liquid/Liquid Extraction
- Supercritical Solvent Extraction

### Size/Adsorptivity/Ionic Characteristics:

- Filtration
- Carbon Adsorption
- Reverse Osmosis
- Ion Exchange
- Electrodialysis

## Important Physical Treatment Data Needs

Data Need	Purpose
<b>For Solids</b>	
Absolute Density	Density Separation
Bulk Density	Storage Volume Required
Size Distribution	Size Modification or Separation
Friability	Size Reduction
Solubility (In H <sub>2</sub> O, organic solvents, oils, etc.)	Dissolution
<b>For Liquids</b>	
Specific Gravity	Density Separation
Viscosity	Pumping & Handling
Water Content (or oil content, etc.)	Separation
Dissolved Solids	Separation
Boiling Pt/Freezing Point	Phase Change Separation, Handling and Storage
<b>For Liquids/Solid Mixtures</b>	
Bulk Density	Storage & Transportation
Total Solids Content	Separation
Solids Size Distribution	Separation
Suspended Solids Content	Separation
Suspended Solids Settling Rate	Separation
Dissolved Solids Content	Separation
Free Water Content	Storage & Transport
Oil and Grease Content	Separation
Viscosity	Pumping and Handling
<b>For Gases</b>	
Density	Separation
Boiling (condensing) Temp.	Phase Change Separation
Solubility (In H <sub>2</sub> O, etc.)	Dissolution

## TECHNOLOGY: Sedimentation

**DESCRIPTION:** Sedimentation is a gravity settling process which allows heavier solids to collect at the bottom of a containment vessel resulting in its separation from the suspending fluid. This type of operation can be accomplished using a batch process or a continuous removal process. There exist several physical arrangements in which the sedimentation process can be applied. These are represented in the diagram shown. The top diagram illustrates a settling pond wherein aqueous waste flows through while the suspended solids are permitted to gravitate and settle out. Occasionally the settled particles (sludges) are removed so this system would be considered a semi-batch process. The middle figure shows a circular clarifier equipped with a solids removal device to facilitate clarification on a continuous process basis resulting in a lower solids content outlet fluid. The third type is a sedimentation basin, as shown in the bottom diagram. It uses a belt-type solids collector mechanism to force the solids to the bottom of the sloped edge of the basin where they are removed. The efficiency of sedimentation treatment is dependent upon the depth and surface area of the basin, settling time (based on the holding time), solid particle size and the flow rate of the fluid.

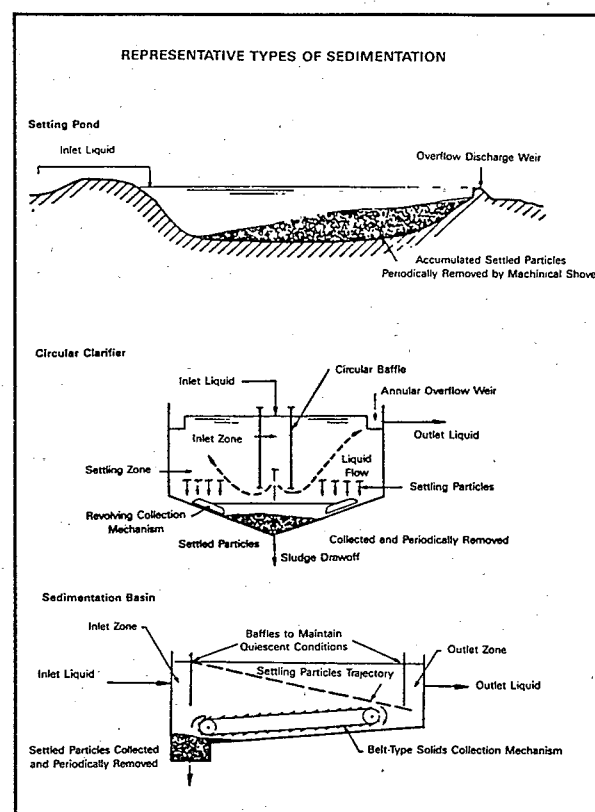
**APPLICABILITY/LIMITATION:** Sedimentation is considered to be a separation process only, and typically, some type of treatment process for the aqueous liquid and the sludges will follow. Its use is restricted to solids that are more dense than water and it is not suitable for wastes consisting of emulsified oils.

**STATUS:** Conventional

**SOURCES:** Chemical Waste Management Inc.  
Dorr Oliver  
Eimco Process Equipment Co.  
Wyo Ben Inc.  
National Hydro Systems Inc.  
Sharples Stokes Div Pennwalt  
Water Tech Inc.  
AFL Industries

### Important Sedimentation Data Needs

Data Need	Purpose
Viscosity of aqueous waste	High viscosity hinders sedimentation
Oil and grease content of waste stream	Not applicable to wastes containing emulsified oils
Specific gravity of suspended solids	Must be greater than 1 for sedimentation to occur



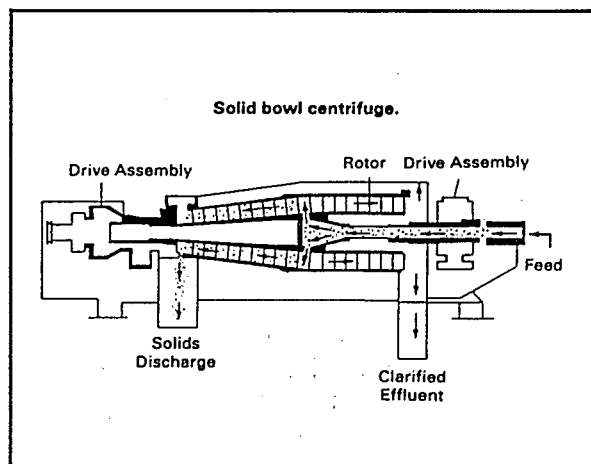
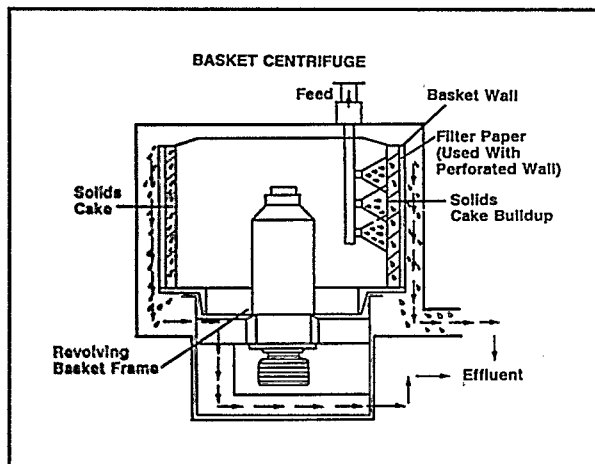
## TECHNOLOGY: Centrifugation

**DESCRIPTION:** Centrifugation is a physical separation process in which the components of a fluid mixture are separated, based on their relative density, by rapidly rotating the fluid mixture within a rigid vessel. Solid particles that are denser than the fluid medium are deposited farthest from the axis of rotation while the liquid supernatant lies separated near the axis. Centripetal forces in centrifugation are similar to gravitational forces in sedimentation except that centripetal forces are thousands of times stronger than gravitational forces, depending upon diameter and rotational speed of the centrifuge.

**AVAILABILITY/LIMITATION:** This treatment is limited to dewatering sludges (including metal-bearing sludges), separating oils from water, and clarification of viscous gums and resins. Centrifuges are generally better suited than vacuum filters for dewatering sticky or gelatinous sludges. Disc-type centrifuges can be used to separate three-component mixtures (e.g., oil, water, solids). Centrifuges often cannot be used for clarification since they may fail to remove less dense solids and those which are small enough to remain in suspension. Recovery and removal efficiencies may be improved if paper or cloth filters are incorporated in the centrifuges.

**STATUS:** Commercially available

**SOURCES:** Clinton Centrifuge Inc.  
ALFA Laval Inc.  
Tetra Recovery Systems  
Dorr-Oliver Inc.  
Bird Environmental Systems  
Western States Machine  
Fletcher  
Astro Metallurgical  
Barrett Centrifugals  
Donaldson Co. Industrial Group  
Donaldson Co. Liquid Sys. Div.  
GCI Centrifuges  
General Productions Svcs Inc.  
IT Corp.  
Ingersoll Rand Environmental  
Master Chemical Corp. Sys. Equip.  
Sartorius Bal Div. Brinkmann  
Sharples Stokes Div.  
Pennwalt  
Tekmar Co.  
Thomas Scientific



## TECHNOLOGY: Flocculation

**DESCRIPTION:** Flocculation is a treatment technology which is used to enhance sedimentation or centrifugation. The waste stream is mixed while a flocculating chemical is added. Flocculants adhere readily to suspended solids and with each other (agglomerate) so that the resultant particles are too large to remain in suspension. Flocculation is primarily used for the precipitation of inorganics.

**AVAILABILITY/LIMITATION:** The extent of completion of flocculation is dependent upon the flow rate of the waste stream, its composition and its pH. This process is not recommended for a waste stream with high viscosity.

**STATUS:** Conventional, demonstrated

**SOURCES:** Refer to buyer's guides

### Important Flocculation Data Needs

Data Need	Purpose
pH of waste	Selection of flocculating agent
Viscosity of waste system	Affects settling of agglomerated solids; high viscosity not suitable
Settling rate of suspended solids	Selection of flocculating agent

## TECHNOLOGY: Oil/Water Separation

**DESCRIPTION:** As in sedimentation, the force of gravity can be used to separate two (or more) immiscible liquids having sufficiently different densities, such as oil and water. Liquid/liquid separation occurs when the liquid mix is allowed to settle. Thus, flow rates in continuous processes must be kept low. The waste flows into a chamber where it is kept quiescent and permitted to settle. The floating oil is skimmed off the top through the use of an oil skimmer while the water or effluent flows out the lower portion of the chamber. Acids may be used to break an oil/water emulsion and enhance this process to allow for greater efficiency in removal of the oil.

**AVAILABILITY/LIMITATION:** The effectiveness of the separation process can be influenced by the waste stream's rate of flow, temperature, and pH. Separation constitutes a pretreatment process if the oil skimmings require further treatment.

**STATUS:** Mobile phase separators are commercially available

**SOURCES:** Refer to buyer's guides

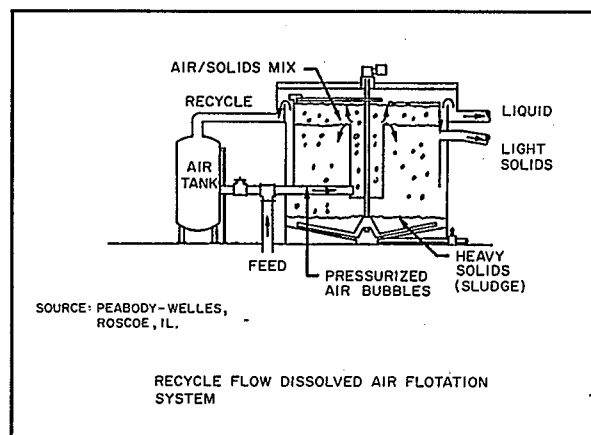
## TECHNOLOGY: Dissolved Air Flotation

**DESCRIPTION:** Dissolved air flotation is a physical process whereby suspended particles or mixed liquids can be removed from an aqueous waste stream. The mixture to be separated is saturated with air (or some other gas such as nitrogen) and typically the pressure is reduced above the treatment tank. As air then comes out of solution, the microbubbles which form can readily adsorb onto suspended solids or oils, enhancing their "flotation" characteristics. In the flotation chamber, separated oil or other "floats" are skimmed off the top while the aqueous liquids flow off the bottom.

**AVAILABILITY/LIMITATION:** This technology is only applicable for waste having densities close to that of water. Air emission controls may be necessary if hazardous volatile organics are present in the waste.

**STATUS:** Conventional

**SOURCES:** Refer to buyer's guides



## TECHNOLOGY: Heavy Media Separation

**DESCRIPTION:** Heavy media separation is a process for separating two solid materials which have significantly different absolute densities. The mixed solids to be separated are placed into a fluid whose specific gravity is chosen (or adjusted) so that the lighter solid floats while the heavier sinks. Usually, the separating fluid (the heavy media) is a suspension of magnetite in water. Specific gravity of the fluid is thus adjustable by varying the amount of magnetite powder used. Magnetite can be easily recovered magnetically from rinsewaters and spills and then reused.

**AVAILABILITY/LIMITATION:** This type of separation is readily used for separating two insoluble solids having different densities. Limitations include the possibility of dissolving solids and ruination of the heavy media, the presence of solids of similar density to those whose separation is desired and the inability to cost-effectively separate magnetic materials (because of the need to recover magnetite).

**STATUS:** Commonly used in the mining industry to separate ores from tailings

**SOURCES:** Tetra Recovery Systems  
Enviro-Chem Waste Management Service

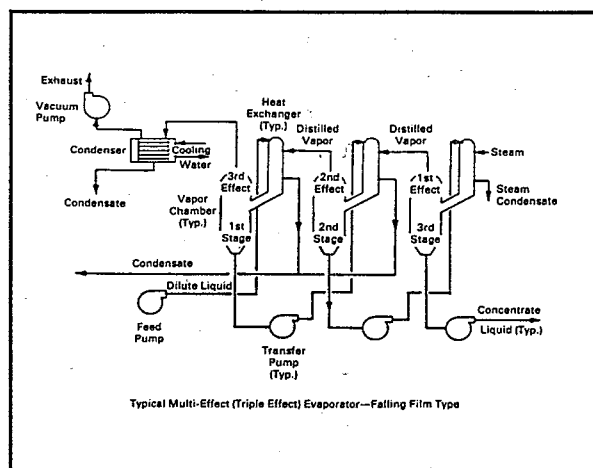
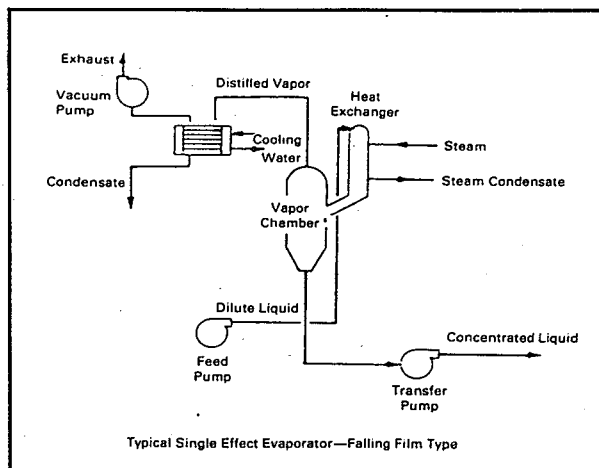
## TECHNOLOGY: Evaporation

**DESCRIPTION:** Evaporation is the physical separation of a liquid from a dissolved or suspended solid by the application of energy to volatilize the liquid. In hazardous waste treatment, evaporation may be used to isolate the hazardous material in one of the two phases, simplifying subsequent treatment. If the hazardous material is in the volatilized phase, the process is usually called "stripping." (See Air Stripping.)

**AVAILABILITY/LIMITATION:** Evaporation can be applied to any mixture of liquids and nonvolatile solids provided the liquid is volatile enough to evaporate under reasonable heating or vacuum conditions (both the liquid and the solid should be stable under those conditions). If the liquid is water, evaporation can be carried out in a large pond provided with solar energy. Evaporation of aqueous wastes can also be done in closed process vessels with energy provided by steam and the resulting water vapor can be condensed for possible reuse. Energy requirements are usually minimized by such techniques as vapor recompression or multiple effect evaporators. Evaporation is applied to solvent waste contaminated with nonvolatile impurities such as oil, grease, paint solids or polymeric resins. Mechanically agitated or wiped thin film evaporators are used. Solvent is evaporated and recovered for reuse. The residue is the bottom stream, typically containing 30 to 50% solids.

**STATUS:** Commercially available

**SOURCES:** Resources Conservation Company (mobile brine concentration systems)  
Kipin Industries  
APV Equipment Inc.  
Ambient Tech. Div. Ameribrom Inc.  
Analytical Bio Chem Labs  
Aqua Chem Water Technologies  
Capital Control Co., Inc.  
Dedert Corp.  
HPD Inc.  
Industrial Filter & Pump Mfg.  
Kimre Inc.  
Kontro Co., Inc.  
Lancy International Inc.  
Licon Inc.  
Rosenmund Inc.  
Sasakura Intl American Corp.  
Spraying Systems Co.  
Votator Anco Votator Div.  
Wallace & Tiernan Div. Pennwalt  
Wastesaver Corp.  
Weathermeasure Weathertronics  
Wheaton Instruments



## TECHNOLOGY: Air Stripping

**DESCRIPTION:** Air stripping is a mass transfer process in which volatile contaminants, in water or soils, are evaporated into the air. Factors important in removal of organics from wastewater via air stripping are temperature, pressure, air to water ratio and surface area available for mass transfer. Air to water volumetric ratios may range from 10:1 up to 300:1. The resulting residuals are the contaminated off gas and the stripped effluent. Volatilized hazardous materials must be recaptured for subsequent treatment to preclude air pollution concerns.

**AVAILABILITY/LIMITATION:** This process is used to treat aqueous organic waste with relatively high volatility, low water solubility (e.g., chlorinated hydrocarbons such as tetrachloroethylene) and aromatics (such as toluene). Limitations include the fact that the process is temperature dependent so that stripping efficiency can be impacted by changes in ambient temperature and the presence of suspended solids may reduce efficiency. If the concentration of VOCs exceeds approximately 100 ppm, some other separation process (e.g., steam stripping) is usually preferred.

**STATUS:** Commercially available

**SOURCES:** OH Materials  
Carbon Air Services  
Detox Inc.  
IT Corporation  
Oil Recovery Systems Inc.  
Resource Conservation Company  
Terra Vac Inc.  
Advanced Industrial Technology  
Baron Blakeslee Inc.  
Beco Engineering Co.  
Calgon Carbon Corp.  
Chem Pro Corp.  
D. R. Technology Inc.  
Delta Cooling Towers  
Detox Inc.  
Hydro Group Inc.  
IPC Systems Inc.  
IT Corp.  
Kimre Inc.  
Munters Corp.  
NEPCCO  
North East Environmental Prods.  
Oil Recovery Systems Inc.  
Tri-Mer Corp.  
Wright R.E. Associates Inc.



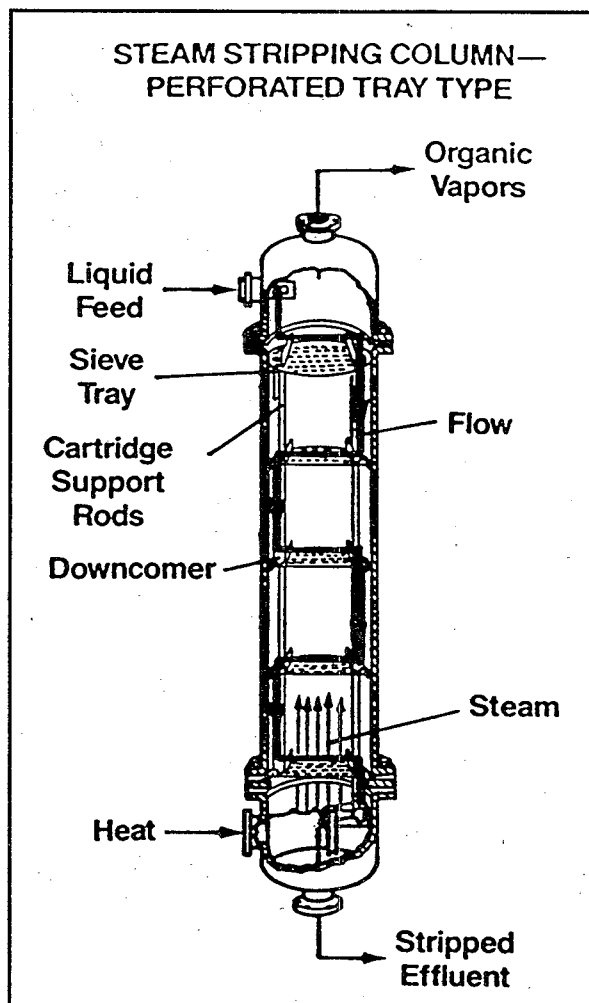
## TECHNOLOGY: Steam Stripping

**DESCRIPTION:** The operation of steam stripping uses steam to evaporate volatile organics from aqueous wastes. Steam stripping is essentially a continuous fractional distillation process carried out in a packed or tray tower. Clean steam, rather than reboiled bottoms, provides direct heat to the column in which gas flows from the bottom to the top of the tower. The resulting residuals are contaminated steam condensate, recovered solvent and stripped effluent. The organic vapors and the raffinate are sent through a condenser in preparation for further purification treatment. The bottoms will require further consideration as well. Possible post-treatments may include incineration, carbon adsorption and land disposal.

**AVAILABILITY/LIMITATION:** Steam stripping is used to treat aqueous wastes contaminated with chlorinated hydrocarbons, aromatics such as xylenes, ketones such as acetone or MEK, alcohols such as methanol and high boiling point chlorinated aromatics such as pentachlorophenol. Steam stripping will treat less volatile and more soluble wastes than will air stripping and can handle a wide concentration range (e.g., from less than 100 ppm to about 10 percent organics). The steam stripping process requires some type of air pollution control (APC) mechanism to eliminate toxic emissions.

**STATUS:** Conventional, well demonstrated

**SOURCES:** Refer to buyer's guides



## TECHNOLOGY: Distillation

**DESCRIPTION:** Distillation is simply the process of evaporation followed by condensation whereby separation of volatile materials can be optimized by controlling both the evaporation-stage temperature (and pressure) and the condenser temperature. Distillation separates miscible organic liquids for solvent reclamation and for waste volume reduction. The resulting residuals are still-bottoms (often containing toxic metals from ink and paint pigments) and intermediate distillate cuts. Two major types of distillation processes are batch distillation and continuous fractional distillation.

**AVAILABILITY/LIMITATION:** Distillation is used to separate liquid organic wastes, primarily spent solvents, for full or partial recovery and reuse. Both halogenated and nonhalogenated solvents can be recovered via distillation. Liquids to be separated must have different volatilities. Distillation for recovery can be limited by the presence of either volatile or thermally reactive suspended solids. If constituents in the input waste streams can form an azeotrope (a specific mixture of liquids exhibiting a maximum or minimum boiling point with the individual constituents) then the energy cost of breaking the azeotrope can be prohibitive.

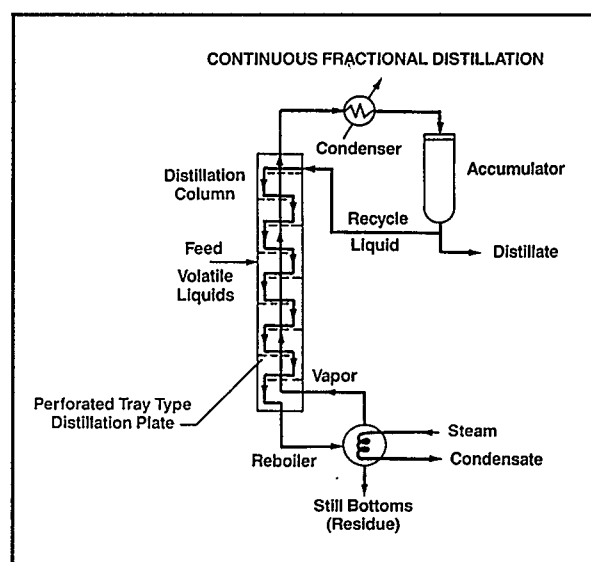
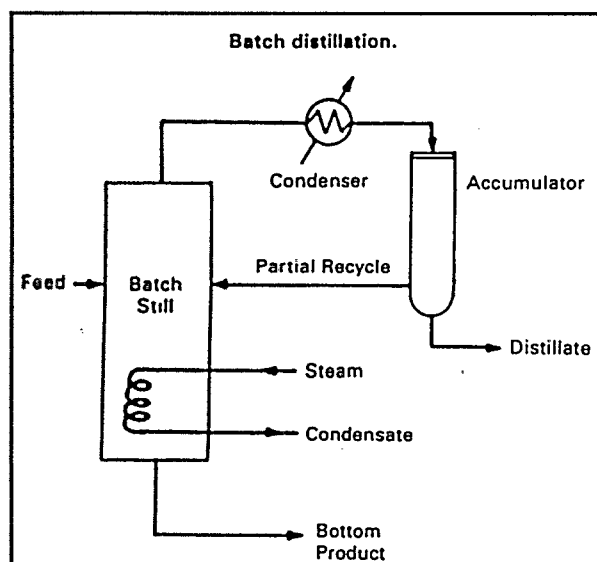
Batch distillation in a heated still pot with condensation of the overhead vapors is easily controlled and flexible, but cannot achieve the high-product purity typical of continuous fractional distillation. Small packaged batch stills treating

one drum per day or less are becoming popular for on-site recovery of solvents. Continuous fractional distillation is accomplished in tray columns or packed towers ranging up to 40 feet in diameter and 200 feet high. Each is equipped with a reboiler, a condenser and an accumulator. The capacity of a unit is a function of the waste being processed, purity requirements, reflux ratio and heat input. Fractional distillation is not applicable for liquids with high viscosity at high temperature, liquids with a high-solids concentration, polyurethanes and inorganics.

**STATUS:** Commercially available

**SOURCES:** Exceltech, Inc.

Kipin Industries  
Mobil Solvent Reclaimers, Inc.  
APV Equipment Inc.  
Ace Glass Inc.  
Artisan Industries Inc.  
Gilmont Instruments Inc.  
Glitsch Inc.  
Hoyt Corp.  
Licon Inc.  
Progressive Recovery Inc.  
Rosenmund Inc.  
Sutcliffe Croftshaw  
Tekmar Co.  
Thomas Scientific  
Vara International Inc.  
Vic Mfg Co. Industrial Div.  
Wheaton Instruments  
York Otto H. Co., Inc.



## **TECHNOLOGY: Soil Flushing/ Soil Washing**

**DESCRIPTION:** Soil flushing is an in-situ extraction of inorganic or organic compounds from soils and is accomplished by passing extractant solvents through the soils using an injection/recirculation process. These solvents may include: water, water surfactant mixtures, acids or bases (for inorganics), chelating agents, oxidizing agents or reducing agents. Soil washing consists of similar treatments, but the soil is excavated and treated at the surface in a soil washer.

**AVAILABILITY/LIMITATION:** Soil flushing/washing fluids must have good extraction coefficients, low volatility and toxicity, be safe and easy to handle, and (most important), be recoverable/ recyclable. This technology is very

promising for extraction of heavy metals from soils, although problems are likely in dry, or in organic-rich soils. Surfactants can be used to extract hydrophobic organisms. Soil characteristics such as type and uniformity are important. Certain surfactants, when tested for in-situ extraction, clogged soil pores and precluded further flushing.

**STATUS:** U.S. EPA Edison, New Jersey, has mobile soil washer, other systems are under development

**SOURCES:** Critical Fluid Systems  
IT Corp.

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## **TECHNOLOGY: Chelation**

**DESCRIPTION:** A chelating molecule contains atoms which can form ligands with metal ions. If the number of such atoms in the molecule is sufficient and if the final molecular shape is such that the metal atom is essentially surrounded then the metal will not be able to form ionic salts which can precipitate out. Thus, chelation is used to keep metals in solution and to aid in dissolution for subsequent transport and removal (e.g., soil washing).

**APPLICABILITY/LIMITATION:** Chelating chemicals can be chosen for their affinity to particular metals (e.g., EDTA and calcium). The presence of fats and oils can interfere with the process.

**STATUS:** Chelating chemicals are commercially available

**SOURCES:** Refer to buyer's guides

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## **TECHNOLOGY: Liquid/Liquid Extraction**

**DESCRIPTION:** Two liquids which are well mixed or are mutually soluble may be separated by liquid/liquid extraction. The process requires that a third liquid be added to the original mix. This third liquid must be a solvent for one of the original components, but must be insoluble in and immiscible with the other. The final solvent/solute stream can be subsequently separated by distillation or by chemical means and the extracting solvent captured for reuse.

**AVAILABILITY/LIMITATION:** Complete separation is rarely achieved, so that some form of post-treatment is required for each separated stream. To effectively recover solvent and solute from the process, other treatments are needed such as distillation or stripping.

**STATUS:** Demonstrated

**SOURCES:** Resources Conservation Co.

## **TECHNOLOGY: Supercritical Extraction**

**DESCRIPTION:** At a certain combination of temperature and pressure, fluids reach their critical point, beyond which their solvent properties are greatly enhanced. For instance, supercritical water is an excellent non-polar solvent in which most organics are readily soluble. These properties make extraction more rapid and efficient than processes using distillation or conventional solvent extraction methods. Presently, the use of supercritical carbon dioxide to extract hazardous organics from aqueous streams is being investigated.

**AVAILABILITY/LIMITATION:** This technology is potentially useful to extract hazardous waste from aqueous streams. Specific applicability and limitations are not yet known.

**STATUS:** Demonstrated on laboratory scale

**SOURCES:** N/A

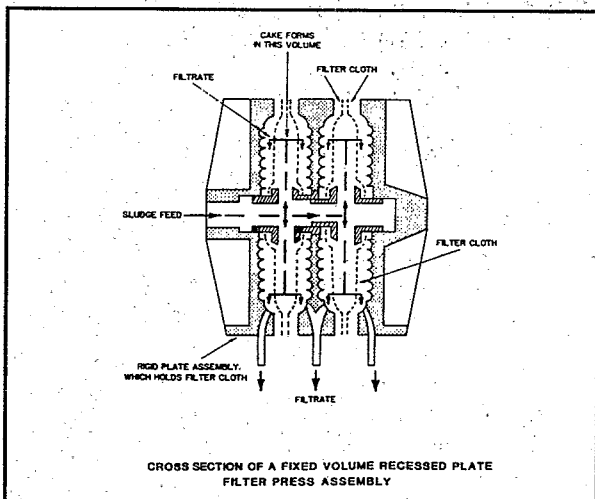
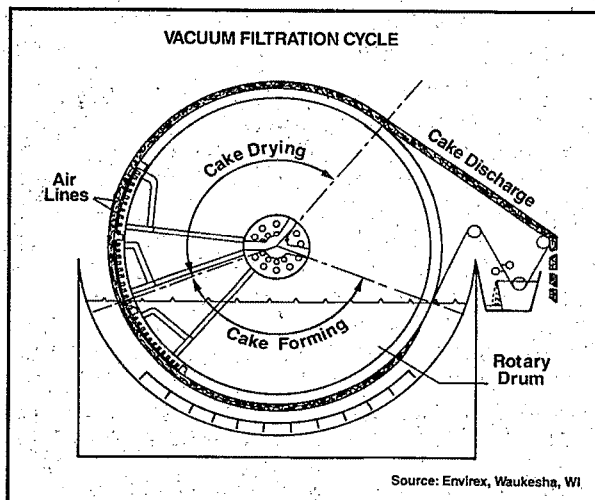
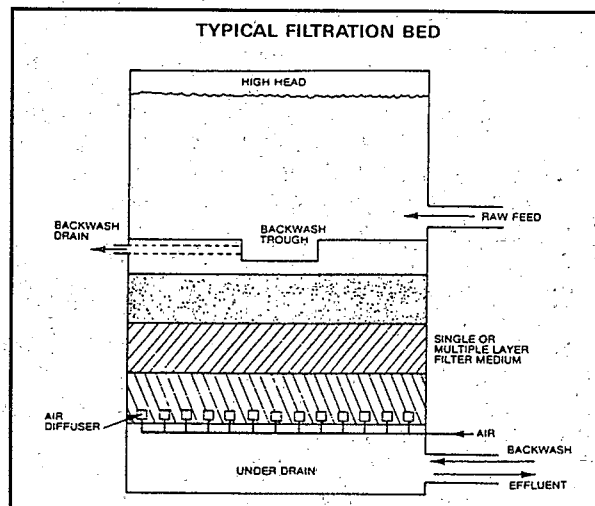
## TECHNOLOGY: Filtration

**DESCRIPTION:** Filtration is a process of separating and removing suspended solids from a liquid by passing the liquid through a porous medium. The porous medium may be a fibrous fabric (paper or cloth), a screen, or a bed of granular material. The filter medium may be pre-coated with a filtration aid such as ground cellulose or diatomaceous earth. Fluid flow through the filter medium may be accomplished by gravity, by inducing a partial vacuum on one side of the medium, or by exerting a mechanical pressure on a dewaterable sludge enclosed by filter media.

**AVAILABILITY/LIMITATION:** Filtration is used for the dewatering of sludges and slurries as a pretreatment for other processes. Granular media filtration is typically used after gravity separation processes for additional removal of suspended solids and oils prior to the other treatment processes. It is also used as a polishing step for treated waste to reduce suspended solids and associated contaminants to low levels. Pretreatment by filtration is appropriate for membrane separation processes, ion exchange, and carbon adsorption in order to prevent plugging or overloading of these processes. Filtration of settled wastes is often required to remove undissolved heavy metals which are present as suspended solids. Filtration does not reduce the toxicity of the waste although sometimes powdered activated carbon may be used as a combination adsorbent and filter aid. Filtration should not be used with sticky or gelatinous sludges, due to the likelihood of filter media plugging.

**STATUS:** Commercially available

**SOURCES:** Calgon Carbon Corp.  
Carbon Air Services Inc.  
Chemical Waste Management  
Industrial Innovations Inc.  
Krauss-Maffei  
Komline Sanderson  
Bird Machine Co.  
D.R. Sperry Inc.  
Dorr-Oliver



## TECHNOLOGY: Carbon Adsorption

**DESCRIPTION:** The chemistry of carbon is such that most organic compounds and many inorganics will readily attach themselves to carbon atoms. The strength of that attachment (and thus, the energy required for subsequent desorption) depends on the bond formed, which in turn, depends on the specific compound being adsorbed. Carbon to be used for adsorption is usually treated to produce a product with large surface-to-volume ratio, thus, exposing a practical maximum number of carbon atoms to be active adsorbers. Carbon so treated is said to be "activated" for adsorption. Activated carbon which has adsorbed so much contaminant that its adsorptive capacity is severely depleted is said to be "spent." Spent carbon can be regenerated, but for strongly adsorbed contaminants, the cost of such regeneration can be higher than simple replacement with new carbon.

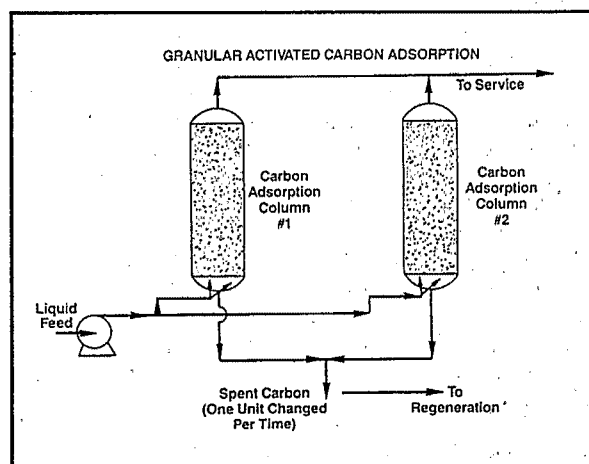
**AVAILABILITY/LIMITATION:** This process is used to treat single-phase aqueous organic wastes with high molecular weight and boiling point and low solubility and polarity, chlorinated hydrocarbons such as tetrachloroethylene, and aromatics such as phenol. It is also used to capture volatile organics in gaseous mixtures. Limitations are usually economic and relate to the rapidity with which the carbon becomes spent. Rule of thumb guidelines are that contaminant concentrations should be less than 10,000 ppm, suspended solids less than 50 ppm, dissolved inorganics and oil and grease less than 10 ppm.

**STATUS:** Conventional, demonstrated

**SOURCES:** Calgon Carbon Corp.  
Carbon Air Services Inc.  
Zimpro Inc.  
Chemical Waste Mgt.

### Important Carbon Adsorption Process

Data Need	Purpose
Chemical characterization of waste stream	Suitability for carbon treatment
Molecular weight	Suitability for carbon treatment
Solubility	Suitability for carbon treatment
Polarity of contaminants to be removed	Suitability for carbon treatment
pH of waste stream	Suitability for carbon treatment



## **TECHNOLOGY: Reverse Osmosis**

**DESCRIPTION:** In normal osmotic processes, solvent will flow across a semi-permeable membrane from a dilute concentration to a more concentrated solution until equilibrium is reached. The application of high pressure to the concentrated side will cause this process to reverse. This results in solvent flow away from the concentrated solution, leaving an even higher concentration of solute. The semi-permeable membrane can be flat or tubular, but regardless of its shape it acts like a filter due to the pressure driving force. In application the waste stream flows past the membrane while the solvent, such as water, is pulled through the membrane's pores and the remaining solutes such as organic or inorganic components do not pass through, but become more and more concentrated on the influent side of the membrane.

**AVAILABILITY/LIMITATION:** For an efficient reverse osmosis process, the chemical and physical properties of the semi-permeable membrane must be compatible with the waste stream's chemical and physical characteristics. Some membranes may be dissolved by some wastes. Suspended solids and some organics will clog the membrane material. Low-solubility salts may precipitate onto the membrane surface.

**STATUS:** Commercial units are available

**SOURCES:** Osmo Membrane Systems

## TECHNOLOGY: Ion Exchange

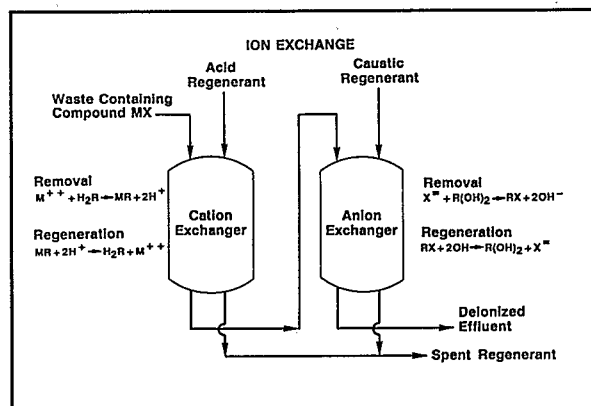
**DESCRIPTION:** Although there are naturally occurring ion exchange media, the process is usually based on the use of specifically formulated resins having an "exchangeable" ion bound to the resin with a "weak ionic" bond. Ion exchange depends upon the electrochemical potential of the ion to be recovered versus that of the exchange ion, and also upon the concentration of the ions in solution. After a critical relative concentration of "recoverable" ion to exchanged ion in solution is exceeded, the exchange resin is said to be "spent." Spent resin is usually recharged by exposing it to a very concentrated solution of the original exchange ion so that a "reverse" exchange takes place, resulting in regenerated resin and a concentrated solution of the removed ion which can then be further processed for recovery and reuse. The process is commonly used to remove toxic metal ions from solution in order to recover concentrated metal solutions for recycling. The resulting residuals include spent resins and spent regenerants such as acid, caustic or brine.

**AVAILABILITY/LIMITATION:** This technology is used to treat metal wastes including cations (e.g.,  $\text{Ni}^{2+}$ ,  $\text{Cd}^{2+}$ ,  $\text{Hg}^{2+}$ ) and anions (e.g.,  $\text{CrO}_4^{2-}$ ,  $\text{SeO}_4^{2-}$ ,  $\text{HAsO}_4^{2-}$ ). Limitations are selectivity/competition, pH and suspended solids. Highly concentrated waste streams (greater than about 25,000 mg/l contaminants) can usually be separated more cost effectively by other means. High solid concentrations (greater than about 50 mg/l) should be avoided to prevent resin blinding.

**STATUS:** Commercially available

### SOURCES:

Calgon  
Dionex  
DeVoe-Holbein  
Davis Instrument Mfg Co., Inc.  
Ecology Protection systems Inc.  
Envirex Inc.  
Industrial Filter & Pump Mfg.  
Lancy International Inc.  
McCormack Corp.  
Osmo Membrane Sys Div.  
Pace International Corp.  
Permutit Co., Inc.  
Serfilco LTD.  
Techni Chem., Inc.  
Thomas Scientific  
Treatment Technologies  
Water Management Inc.  
Western Filter Co.



## TECHNOLOGY: Electrodialysis

**DESCRIPTION:** Electrodialysis concentrates or separates ionic species contained in a water solution. In electrodialysis, a water solution is passed through alternately placed cation-permeable and anion-permeable membranes. An electrical potential is applied across the membrane to provide the motive force for the ion migration. The ion-selective membranes are thin sheets of ion exchange resin reinforced by a synthetic fiber backing.

**AVAILABILITY/LIMITATION:** The process is well established for purifying brackish water, and recently has been demonstrated for recovery of metal salts from plating rinse.

**STATUS:** Units are being marketed to reclaim metals of value from rinse streams. Such units can be skid mounted and require only piping and electrical connections.

**SOURCES:** Centec Corp.



## CHEMICAL TREATMENT PROCESSES

The treatment processes discussed in this section include most of those commonly used for waste treatment applications. These include

- pH Adjustment (for Neutralization or Precipitation)
- Hydrolysis and Photolysis
- Oxidation and Reduction
- Hydrogen Peroxide Oxidation
- Ozonation
- Alkaline Chlorination
- Hypochlorite Chlorination
- Electrolytic Oxidation
- Chemical Dechlorination

### Important Chemical Treatment Data Needs\*

Data Need	Purpose
pH	pH Adjustment Needs, Corrosivity
Turbidity/Opacity	Photolysis
Constituent analysis	Treatment Need
Halogen Content	Dehalogenation

\* Generally, the data needs for evaluating and comparing chemical treatment technologies include the data needs identified for physical treatment technologies

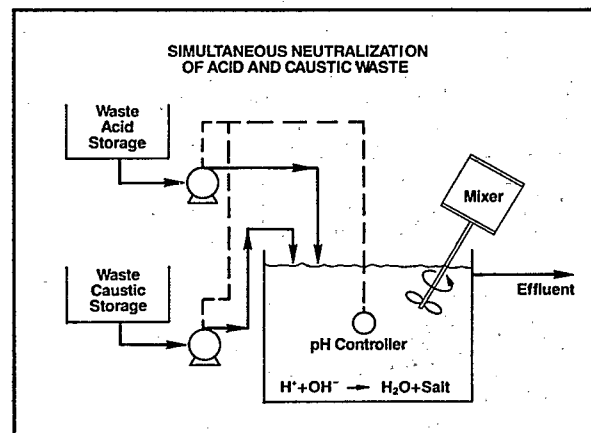
## TECHNOLOGY: Neutralization

**DESCRIPTION:** When an ionic salt is dissolved in water, several of the water molecules break into their ionic constituents of  $H^+$  and  $OH^-$ . Neutralization is the process of changing the constituents in an ionic solution until the number of hydrogen ions ( $H^+$ ) present is balanced by the number of hydroxyl ( $OH^-$ ) ions. The lack of balance is measured in terms of the hydrogen ion ( $H^+$ ) concentration and is commonly called the pH of the solution. Neutrality is given on the pH scale as 7, while an excess of  $H^+$  ions (acidity) is a number between 0 and 7 and an excess of hydroxide ions ( $OH^-$ ) (alkalinity) is indicated by a number between 7 and 14. Neutralization is used to treat waste acids and waste alkalies (bases) in order to eliminate or reduce their reactivity and corrosiveness. Neutralization can be a very inexpensive treatment, especially if waste alkali can be used to treat waste acid and vice versa. Residuals include a neutral effluent containing dissolved salts and any precipitated salts.

**APPLICABILITY/LIMITATION:** The process should be performed in a well-mixed system to ensure completeness. Care should be taken to ensure compatibility of the waste and treatment chemicals to prevent the formation of more toxic or more hazardous compounds than were originally present.

**STATUS:** Common industrial process

**SOURCES:** Refer to buyer's guides for chemical suppliers



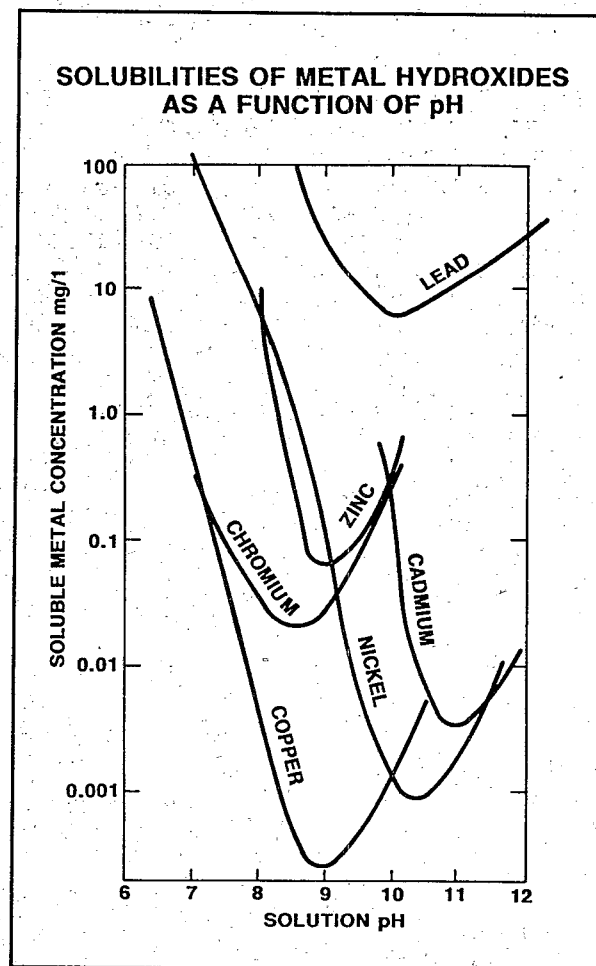
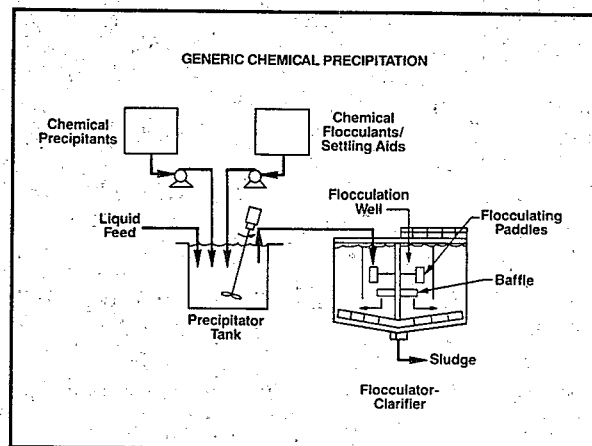
## TECHNOLOGY: Chemical Precipitation

**DESCRIPTION:** Like neutralization, chemical precipitation is a pH adjustment process. To achieve precipitation, acid or base is added to a solution to adjust the pH to a point where the constituents to be removed have their lowest solubility. Chemical precipitation facilitates the removal of dissolved metals from aqueous wastes. Metals may be precipitated from solution as hydroxides, sulfides, carbonates, or other insoluble salts. Hydroxide precipitation with lime is most common, however, sodium sulfide is sometimes used to achieve lower effluent metal concentrations. Solid separation is effected by standard flocculation/coagulation techniques. The resulting residuals are metal sludge and the treated effluent which has an elevated pH and (in the case of sulfide precipitation) excess sulfide.

**APPLICABILITY/LIMITATION:** This technology is used to treat aqueous wastes containing metals. Limitations include the fact that not all metals have a common optimum pH at which they precipitate. Chelating and complexing agents can interfere with the process. Organics are not removed except through adsorptive carryover. The resulting sludge may be hazardous by definition but often may be delisted by specific petition.

**STATUS:** Commercially available

**SOURCES:** Mobile Systems-Rexnord Craig  
Ecolochem Inc.  
Dravo Corp.  
Detox Inc.  
Envirochem Waste Management Services  
Chemical Waste Management Inc.  
Andco Environmental Processes Inc.  
Ensotech Inc.  
Tetra Recovery Systems



## **TECHNOLOGY: Chemical Hydrolysis**

**DESCRIPTION:** Hydrolysis is the process of breaking a bond in a molecule (which is ordinarily not water soluble) so that it will go into ionic solution with water. Hydrolysis can be achieved by the addition of chemicals (e.g., acid hydrolysis), by irradiation (e.g., photolysis) or biologically (e.g., enzymatic bond cleavage). The cloven molecule can then be further treated by other means to reduce toxicity.

**APPLICABILITY/LIMITATION:** Chemical hydrolysis is applicable to a wide range of otherwise

refractory organics. Acid hydrolysis as in-situ treatment must be performed carefully because of the potential to mobilize any heavy metals present.

**STATUS:** Common industrial process

**SOURCES:** Refer to buyer's guides for chemical suppliers

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## **TECHNOLOGY: Ultraviolet Photolysis**

**DESCRIPTION:** Ultraviolet photolysis (UV) is a process that destroys or detoxifies hazardous chemicals in aqueous solutions utilizing UV irradiation. Adsorption of energy in the UV spectrum results in a molecule's elevation to a higher energy state, thus, increasing the ease of bond cleavage and subsequent oxidation of the molecule. For example, ultraviolet light has been used for degradation of dioxins in waste sludge. This process requires extraction of the waste to be destroyed into a clean transparent solvent. Reaction products are dechlorinated materials and free chlorine gas. Use of UV photolysis on

nitrate wastes has been successfully demonstrated on a pilot scale.

**APPLICABILITY/LIMITATION:** The inability of UV light to penetrate and destroy pollutants in soil or in turbid or opaque solutions is a limitation of this approach. Photolytic treatment can be enhanced by simultaneous introduction of ozone or hydrogen peroxide.

**STATUS:** Laboratory scale

**SOURCES:** SYNTEX

## **TECHNOLOGY: Chemical Oxidation (Chemical Reduction)**

**DESCRIPTION:** Oxidation and reduction must both take place in any such reaction. In any oxidation reaction the oxidation state of one compound is raised (i.e., oxidized) while the oxidation state of another compound is lowered (i.e., reduced). Oxidation and reduction reactions are utilized to change the chemical form of a hazardous material in order to render it less toxic or to change its solubility, stability, separability or otherwise change it for handling or disposal purposes. In the reaction, the compound supplying the oxygen (or chlorine or other negative ion) is called the oxidizer or oxidizing agent while the compound accepting the oxygen (i.e., supplying the positive ion) is called the reducing agent. The reaction can be enhanced by catalysis, electrolysis or irradiation.

The process is called chemical reduction when its purpose to lower the oxidation state of a compound. Typical reducing agents include: iron, aluminum, zinc and sodium compounds.

For the reduction process to occur efficiently, the pH of the waste should be adjusted to an appropriate level. After this stage is accomplished, the reducing agent is added and the resulting solution is mixed until the reaction is completed. This treatment may be applied to chemicals such as hexavalent chromium, mercury and lead. It is likely that other treatment processes may be used in conjunction with chemical reduction.

**APPLICABILITY/LIMITATION:** The process is nonspecific. Solids must be in solution. Reactions can be explosive. Waste composition must be well known to prevent the inadvertent production of a more toxic or more hazardous end product.

**STATUS:** Conventional process

**SOURCES:** Refer to buyer's guides for specific process application

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## **TECHNOLOGY: Oxidation by Hydrogen Peroxide (H<sub>2</sub>O<sub>2</sub>)**

**DESCRIPTION:** This treatment technology is based on the addition of hydrogen peroxide to oxidize organic compounds. Hydrogen peroxide is not the stable oxide of hydrogen and since it readily gives up its extra oxygen, it is an excellent oxidizing agent.

**APPLICABILITY/LIMITATION:** The process is a nonspecific reaction. It may be exothermic/explosive or require addition of heat and/or catalysts. Oxidation by hydrogen peroxide is probably not applicable for in-situ treatment. However, it may be used for surface treatment of contaminated groundwaters/sludges.

**STATUS:** Common industrial process

**SOURCES:** Refer to buyer's guides

## **TECHNOLOGY: Ozonation**

**DESCRIPTION:** Ozone is an oxygen molecule containing three oxygen atoms. It is relatively unstable and thus, is chemically ideal as an oxidizing agent. Ozonation is a chemical oxidation process appropriate for aqueous streams which contain less than 1 percent oxidizable compounds.

**APPLICABILITY/LIMITATION:** Ozone can be used to pretreat wastes to break down refractory organics or as a polishing step after biological or other treatment processes to oxidize untreated organics. Ozone is usually produced by high-voltage ionization of atmospheric oxygen

(O<sub>2</sub>). Ozone is currently used for treatment of hazardous wastes to destroy cyanide and phenolic compounds. The rapid oxidation of cyanides with ozone offers advantages over the slower alkaline chlorination method. Limitations include the physical form of the waste (i.e., sludges and solids are not readily treated) and non-selective competition with other species.

**STATUS:** Commercially available

**SOURCES:** Refer to buyer's guides

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## **TECHNOLOGY: Alkaline Chlorination**

**DESCRIPTION:** When chlorine is added to wastewaters, under alkaline conditions, reactions occur which lead to oxidation (chlorination) of the contaminant. This oxidation process, which is widely used in the treatment of cyanide wastes, is generally referred to as the "alkaline chlorination" process. Cyanides can be oxidized with chlorine to the less toxic cyanates. Additional chlorine will then oxidize the cyanates to nontoxic nitrogen gas, carbon dioxide, and bicarbonates.

**APPLICABILITY/LIMITATION:** Alkaline chlorination is used to treat free cyanides and com-

plex cyanides although combinations with Fe or Ni will take a longer time. Limitations include the exothermic heat of the reaction, non-selective competitions with other species and additional chlorine demands. Fairly close pH control (7.5 to 9.0) is required to avoid toxic volatiles release.

**STATUS:** Commercially available

**SOURCES:** Refer to buyer's guides

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## **TECHNOLOGY: Oxidation by Hypochlorite**

**DESCRIPTION:** This process consists of adding sodium or calcium hypochlorite (bleaching agents) to oxidize organic wastes. Such technology will be recognized as the common method of disinfecting home swimming pools.

**APPLICABILITY/LIMITATION:** This method may produce toxic chlorinated organic by-products and it must be done under controlled (not in-situ)

conditions, i.e. batch reactors. It is a nonspecific reaction.

**STATUS:** Commercially available

**SOURCES:** Refer to buyer's guides

## **TECHNOLOGY: Electrolytic Oxidation**

**DESCRIPTION:** In this process cathodes and anodes are immersed in a tank containing a waste to be oxidized, and a direct electrical current is imposed on the system. The process is particularly applicable to cyanide bearing wastes. Reaction products are ammonia, urea, and carbon dioxide. During the decomposition, metals present are plated out on the cathodes.

**APPLICABILITY/LIMITATION:** Electrolytic oxidation is used to treat high concentrations (up to ~10 percent) of cyanide and to separate met-

als to allow their potential recovery. Limitations include physical form of the feed (solids must be dissolved), non-selective competition with other species and long-process times. Electrolytic recovery of single metal species can be high (90 percent and higher).

**STATUS:** Commercially available

**SOURCES:** Refer to buyer's guides

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## **TECHNOLOGY: Catalytic Dehydrochlorination**

**DESCRIPTION:** Catalytic Dehydrochlorination is based on the reaction of polychlorinated hydrocarbons with high pressure hydrogen gas in the presence of a catalyst. The feed must be in either a liquid or gaseous form with the inorganic and inert constituents removed. The operating temperatures are: 350 to 375°C under 30 to 50 atm pressure. The quantity of catalysts is usually less than 1 percent of pollutant weight.

**APPLICABILITY/LIMITATION:** In general, supported catalysts are quickly deactivated by impurities such as tars or sulfur compounds. These processes are costly and often require the use of hazardous chemicals as catalysts.

**STATUS:** Laboratory scale

**SOURCES:** Not applicable

## **TECHNOLOGY: Alkali Metal Dechlorination**

**DESCRIPTION:** The purpose of this process of chemical dechlorination is to displace chlorine from chlorinated organic compounds contained in oils and liquid wastes. Typically the waste is filtered before it enters the reactor system where it encounters the dechlorinating reagent. The great affinity of alkali metals for chlorine (or any halide) is the chemical basis of the process. Successive treatment includes additional centrifugation and filtration. By-products include chloride salts, polymers and sometimes heavy metals. This process may be carried out in a reactor system (as mentioned above), in situ or by excavation techniques. Several chemical dechlorination processes are based on a method developed by the Goodyear Tire and Rubber Company in 1980. The original method uses sodium naphthalene and tetrahydrofuran to strip chlorine atoms from PCBs, resulting in polymerizing the biphenols into an inert condensable sludge. The reactor is blanketed with nitrogen because reagents are sensitive to air and to

water and an excess of reagent to chlorine content is required. The Goodyear Company has not commercially developed the technology. However several companies have modified the method by substituting their own proprietary reagent for the naphthalene. The equipment is mobile and can be transported on semi-trailors.

**APPLICABILITY/LIMITATION:** Such processes are used to treat PCBs, other chlorinated hydrocarbons, acids, thiols, and dioxins. Moisture content adversely affects rates of reaction and dewatering should be a pretreatment step. Waste stream concentrations are also important.

**STATUS:** Commercially available

**SOURCES:** American Mobile Purification  
SunOhio  
PPM Inc.  
Acurex  
Chemical Waste Management Inc.  
Exceltech, Inc.

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## **TECHNOLOGY: Alkali Metal/ Polyethylene Glycol (A/PEG)**

**DESCRIPTION:** In 1978, the EPA sponsored research which led to the development of the first of the series of A/PEG reagents, which were shown to effectively dechlorinate PCBs and oils. Essentially, these reagents were alkali metal/polyethylene glycols which react rapidly to dehalogenate halo-organic compounds of all types, under both ambient and high temperature conditions. In the A/PEG reagents, the alkali metal ion is held in solution by the large polyethylene glycol anion. PCBs and other halogenated molecules are uniquely soluble in A/PEG reagents. These qualities combine to get a single-phase system in which the anions readily displace the halogen atoms. The reaction of halogenated aromatics with PEGs result in the substitution of the PEG for the chlorine atom to form a PEG ether. The PEG ether, in turn, may then decompose to a phenol.

**APPLICABILITY/LIMITATION:** In this treatment, heat and excess reagent are required for the process to function effectively in soils containing more than seven percent moisture.

**STATUS:** Process has been field tested

**SOURCES:** Not applicable



## BIOLOGICAL PROCESSES

Biological degradation of hazardous organic substances is a viable approach to waste management. The most commonly used processes are those originally utilized in the treatment of municipal wastewaters, namely, processes based on aerobic bacteria or anaerobic bacteria. In-situ treatment of contaminated soils can also be performed biologically. Cultures used in biological degradation processes can be native (indigenous) microbes, selectively adapted microbes or genetically altered microorganisms.

Some processes based on other biological communities (such as fungi) are under development and evaluation, but have not been fully demonstrated.

### Important Biological Treatment Data Needs

Data Need	Purpose
Gross Organic Component (BOD, TOC)	Treatability
Priority Pollutant Analysis	Toxicity to Process Microbes
Dissolved Oxygen	Aerobic Reaction Rates/ Interference with Anaerobic System
Nutrient Analysis (NH <sub>3</sub> , NO <sub>3</sub> , PO <sub>4</sub> , etc.)	Nutrient Requirements
pH	pH Adjustment
ORP	Chemical Competition

## **TECHNOLOGY: Aerobic Biological Treatment**

**DESCRIPTION:** Hydrocarbons are catabolized (broken down to simpler substances) by microorganisms using three general mechanisms. These are aerobic respiration, anaerobic respiration and fermentation. In general, aerobic degradation processes are more often used for biodegradation because the degradation process is more rapid and more complete, and problematic end products (methane, hydrogen sulfide) are not produced. However, anaerobic degradation is important for dehalogenation. (See anaerobic process description in this document).

In aerobic respiration, organic molecules are oxidized to carbon dioxide ( $\text{CO}_2$ ) and water and other end products using molecular oxygen as the terminal electron acceptor. Oxygen may also be incorporated into intermediate products of microbial catabolism through the action of oxidase enzymes, making them more susceptible to further biodegradation. Microorganisms metabolize hydrocarbons by anaerobic respiration in the absence of molecular oxygen using inorganic substrates as terminal electron acceptors. Naturally occurring aerobic bacteria can decompose organic materials of both natural and synthetic origin to harmless or stable forms or both by mineralizing them to  $\text{CO}_2$  and water. Some anthropogenic compounds can appear relatively refractory to biodegradation by naturally occurring microbial populations because of the interactions of environmental influences, lack of solubility, absence of required enzymes, nutrients, or other factors. However, the use of properly selected or engineered microbial populations, maintained under environmental conditions most conducive to their metabolic activity can be an important means of biologically transforming or degrading these otherwise refractory wastes.

All microorganisms require adequate levels of inorganic and organic nutrients, growth factors

(vitamins, magnesium, copper, manganese, sulfur, potassium, etc.), water, oxygen, carbon dioxide and sufficient biological space for survival and growth. One or more of these factors are usually in limited supply. In addition, various microbial competitors adversely affect each other through the struggle for these limiting factors. Other factors which can influence microbial biodegradation rates include microbial inhibition by chemicals in the waste to be treated, the number and physiological state of the organisms as a function of available nutrients, the seasonal state of microbial development, predators, pH and temperature. Interactions between these and other potential factors can cause wide variations in degradation kinetics. For these and other reasons, aerobic biodegradation is usually carried out in processes in which all or many of the requisite environmental conditions can be controlled. Such processes include conventional activated sludge processes as well as modifications such as sequencing batch reactors, and aerobic-attached growth biological processes such as rotating biological contactors and trickling filters. Recent developments with genetically engineered bacteria have been reported to be effective for biological treatment of specific hazardous wastes which are relatively uniform in composition.

**APPLICABILITY/LIMITATION:** Used to treat aqueous wastes contaminated with low levels (e.g., BOD less than  $\approx 10,000 \text{ mg/l}$ ) of nonhalogenated organic and/or certain halogenated organics. The treatment requires consistent, stable operating conditions.

**STATUS:** Conventional, broadly used technology

**SOURCES:** Dependent upon specific engineered approach — see following discussions

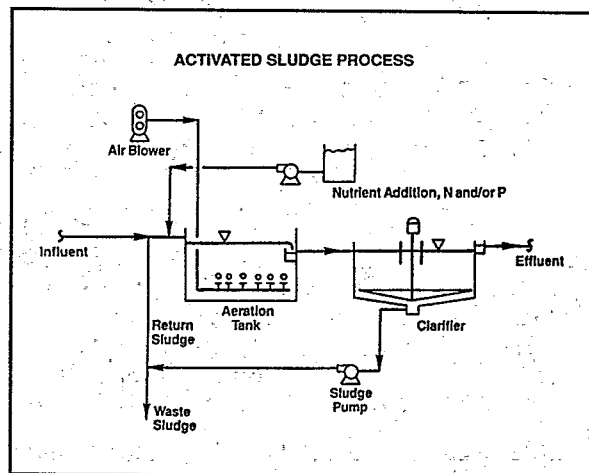
## TECHNOLOGY: Activated Sludge

**DESCRIPTION:** The function of activated sludge treatment is to break down organic contaminants in aqueous waste streams through the activity of aerobic microorganisms. These microorganisms metabolize biodegradable organics. This treatment includes conventional activated sludge processes as well as modifications, such as sequencing batch reactors. The aeration process includes pumping the waste to an aeration tank where the biological treatment occurs. Following this the stream is sent to a clarifier where the liquid effluent (treated aqueous waste) is separated from the sludge biomass. Aerobic processes are capable of significantly reducing a wide range of organic, toxic and hazardous compounds. However, only dilute aqueous waste (less than  $\approx 1$  percent) are normally treatable.

**APPLICABILITY/LIMITATION:** The treatment requires consistent stable operating conditions. Activated sludge processes are not suitable for removing highly chlorinated organics, aliphatics, amines and aromatic compounds from a waste stream. Some heavy metals and organic chemicals are harmful to the organisms. When utilizing conventional open aeration tanks and clarifiers, this technology can result in the escape of volatile hazardous materials.

**STATUS:** Conventional, well developed

**SOURCES:** Polybac Corp.  
Detox Inc.  
Ground Decontamination Systems



## TECHNOLOGY: Rotating Biological Contactors

**DESCRIPTION:** Rotating biological contactors aerobically treat aqueous waste streams, especially those containing alcohols, phenols, phthalates, cyanides and ammonia. The process consists of primary treatment for solids removal followed by the rotating biological contactors where the waste stream comes into contact with the microbial film and the atmosphere. The rate of rotation can be varied to optimize oxygenation of the bacteria and their contact time with the wastes to be degraded. Effluent is then sent to a secondary clarifier.

**APPLICABILITY/LIMITATION:** Rotating biological contactors are not a sufficient method to remove highly chlorinated organics, aliphatics, amines and aromatic compounds. Some heavy metals and organic chemicals are harmful to the organisms.

**STATUS:** Conventional

**SOURCES:** Polybac Corp.  
Detox Inc.  
Ground Decontamination Systems

### Important Data Needs for Screening RBCs:

Data Need	Purpose
Gross organic components (BOD, TOC)	Waste strength, treatment duration
Priority pollutant analyses (organics, metals, pesticides, CN, phenols)	Suitability for treatment, toxic impact assessment
Influent temperature	Feasibility in climate

## TECHNOLOGY: Bioreclamation

**DESCRIPTION:** Bioreclamation is used to treat contaminated areas through the use of aerobic microbial degradation. It may be accomplished by in-situ treatment using injection/extraction wells or an excavation process. Extracted waters, leachates or wastes are oxygenated, nutrients and bacteria are added and the liquids reinjected in the ground. Bacteria then can degrade wastes still in the soil. The treatment has been successfully applied to biodegradable nonhalogenated organics to reduce the contaminated levels in soils and groundwater.

**APPLICABILITY/LIMITATION:** For in-situ treatment, limitations would include site geology and hydrogeology which could restrict pumping and extraction of hazardous wastes, along with reinjection and recirculation. Ideal soil conditions are those with neutral pH, high permeability and a moisture content of 50 to 75 percent.

**STATUS:** Demonstrated

**SOURCES:** FMC

### Important Bioreclamation Data Needs

Data Need	Purpose
Gross organic components (BOD, TOC)	Waste strength, treatment duration
Priority analysis	Identify refractory and biodegradable compounds, toxic impact
Microbiology cell enumerations	Determine existence of dominant bacteria
Temperature	Feasibility in climate
Dissolved oxygen	Rate of reaction
pH	Bacteria preference
Nutrient analysis NH <sub>3</sub> , NO <sub>3</sub> , PO <sub>4</sub> , etc.	Nutrient requirements

## TECHNOLOGY: Anaerobic Digestion

**DESCRIPTION:** All anaerobic biological treatment processes achieve the reduction of organic matter, in an oxygen-free environment, to methane and carbon dioxide. This is accomplished by using cultures of bacteria which include facultative and obligate anaerobes. Anaerobic bacterial systems include hydrolytic bacteria (catabolize saccharides, proteins, lipids); hydrogen producing acetogenic bacteria (catabolize the products of hydrolytic bacteria, e.g., fatty acids and neutral end products); homolactic bacteria (catabolize multicarbon compounds to acetic acid); and methanogenic bacteria (metabolize acetic and higher fatty acids to methane and carbon dioxide). The strict anaerobes require totally oxygen-free environments and oxidation reduction potential of less than -0.2V. Microorganisms in this group are commonly referred to as methanogenic consortia and are found in anaerobic sediments or sewage sludge digesters. These organisms play an important role in reductive dehalogenation reactions, nitrosamine degradation, reduction of epoxides to olefins, reduction of nitro groups and ring fission of aromatic structures. Available anaerobic treatment concepts are based on such approaches as the classic well-mixed system, the two-stage systems and the fixed bed. In the well-mixed digester system a single vessel is used to contain the wastes being treated and all bacteria must function in that common environment. Such systems typically require long retention times and the balance between acetogenic and methanogenic populations is easily upset. In the two stage approach, two vessels are used to maintain separate environments, one optimized for the acetogenic bacteria (pH 5.0), and the other optimized for the methanogenic bacteria (pH 7.0). Retention times are significantly lower and upsets are uncommon

in this approach. The fixed bed approach (for single or 2-staged systems) utilizes an inert solid media to which the bacteria attach themselves and low solids wastes are pumped through columns of such bacteria rich media. Use of such supported cultures allows reduced retention times since bacterial loss through washout is minimized. Organic degradation efficiencies can be quite high. A number of proprietary engineered processes based on these types of systems are actively being marketed, each with distinct features but all utilizing the fundamental anaerobic conversion to methane and carbon dioxide.

**APPLICABILITY/LIMITATION:** This process is used to treat aqueous wastes with low to moderate levels of organics. Anaerobic digestion can handle certain halogenated organics better than aerobic treatment. Stable, consistent operating conditions must be maintained. Anaerobic degradation can take place in native soils but when used as a controlled treatment process, an airtight reactor is required. Since methane and CO<sub>2</sub> gases are formed, it is common to vent the gases or burn them in flare systems. However, volatile hazardous materials could readily escape via such gas venting or flare systems. Thus, controlled off-gas burning could be required. Alternatively, depending on the nature of the waste to be treated, the off-gas could be used as a source of energy.

**STATUS:** Available and widely used in POTWs

**SOURCES:** Refer to buyer's guides

## **TECHNOLOGY: White-rot Fungus**

**DESCRIPTION:** The lignin degrading white-rot fungus (*phanerochaete chrysosporium*) has been found to degrade a broad spectrum of organopollutants including chlorinated lignin-derived by-products of the Kraft pulping process. White-rot has been shown to degrade aliphatic, aromatic and heterocyclic compounds. Specifically, white-rot fungus has been shown to degrade lindane, benzo(a)pyrene, DDT, TCDD, and PCBs to innocuous end products. The studies performed, to date, suggest that white-rot fungus may prove to be an extremely useful microorganism in the biological treatment of hazardous organic waste.

**APPLICABILITY/LIMITATION:** Demonstrated on laboratory scale

**STATUS:** This technology is in the developmental phase and has been applied only in laboratory-type test environs

**SOURCES:** N/A

## THERMAL DESTRUCTION PROCESS

While limits exist for specific incineration technologies, there are no limits for any wastes, i.e., any waste can be burned at some cost. This includes several energy recovery processes, traditional incineration, and several innovative thermal processes.

Technical limitations on destruction processes and several innovative

Data Need	Important Thermal Treatment Data and Purpose
Heat Content (HHV and LHV)	Combustibility
Volatile Matter Content	Furnace Design
Ash Content	Furnace Design, Handling
Ash Characteristics	Furnace Design
Halogen Content	Refractory Design, Flue Gas Ductwork Specification, APC Requirements
Moisture Content	Auxiliary Fuel Requirements
Heavy Metal Content	Air Pollution Control

\* Generally, the data needs for evaluating thermal processes include treatment for the purpose of feed mechanism design

needed for physical

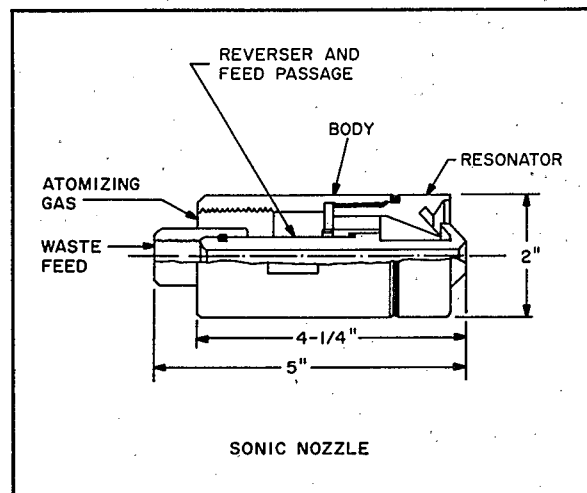
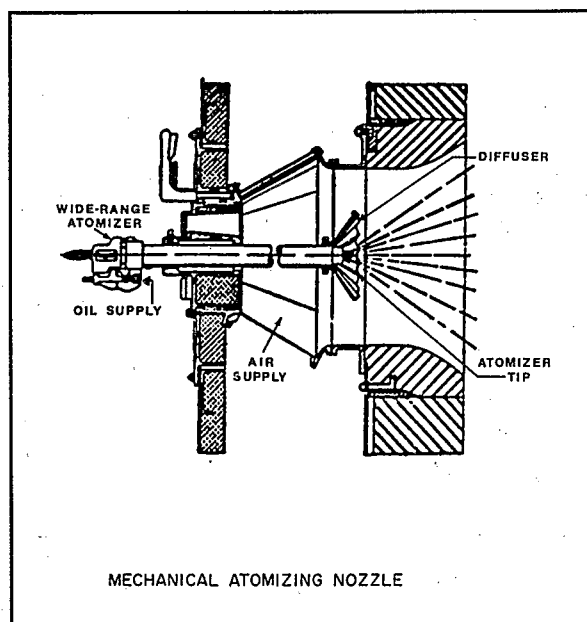
## TECHNOLOGY: Liquid Injection Incineration

**DESCRIPTION:** Liquid waste material is introduced to the combustion chamber by means of specially designed nozzles. Different nozzle designs result in various droplet sizes which mix with air and fuel as needed. Following combustion, the resulting gases are cooled and treated to remove particulates and to neutralize acid gases. Pretreatment such as blending, may be required for feeding some wastes to specific nozzles to provide efficient mixing with the oxygen source and to maintain a continuous homogeneous waste flow. In general, the more finely atomized liquids will combust more rapidly and more completely. Operating temperatures range from 1200 to 1300° F and the gas residence time ranges from 0.1 to 2 seconds. Typical heat output ranges from 1 to 100 MMBtu/hr.

**APPLICABILITY/LIMITATION:** Liquid injection incineration can be applied to all pumpable organic wastes including wastes with high moisture content. Care must be taken in matching waste (especially viscosity and solids content) to specific nozzle design. Particle size is a relevant consideration so the wastes do not clog the nozzle. Emission control systems will probably be required for wastes with ash content above 0.5 percent (particulate control) or for halogenated wastes (acid gas scrubbers).

**STATUS:** This process is conventional and well demonstrated

**SOURCES:** Ensco Environmental Services  
TRANE Thermal Co.  
John Zink Co.  
Coen Co. Inc.  
Vent-o-Matic Incinerator Corp.  
Lotepro Co.





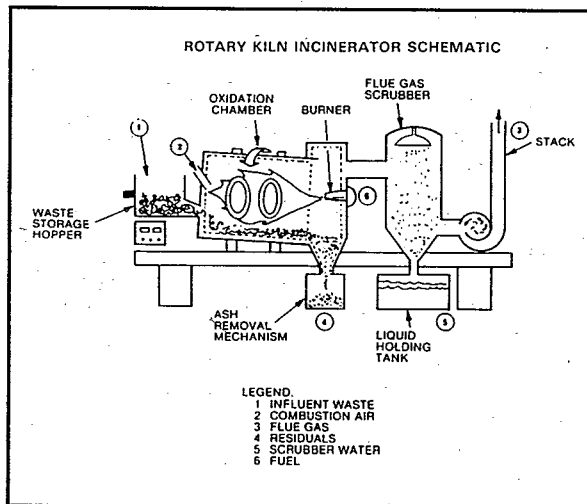
## TECHNOLOGY: Rotary Kiln Incineration

**DESCRIPTION:** A rotary kiln incinerator is essentially a long, inclined tube that is rotated slowly. Wastes and auxiliary fuels are introduced to the high end of the kiln and the rotation constantly agitates (tumbles) the solid materials being burned. This tumbling causes a great amount of turbulence and allows for improved combustion. Rotary kilns are intended primarily for solids combustion, but liquids and gases may be co-incinerated with solids. Exhaust gases from the kiln pass to a secondary chamber or afterburner for further oxidation. Ash residue is discharged and collected at the low end of the kiln. Exhaust gases require acid gas and particulate removal through the use of a gas scrubber and the ashes may require solidification before landfilling.

**APPLICABILITY/LIMITATION:** Most types of solid, liquid, and gaseous organic waste or a mixture of these wastes can be treated with this technology. Explosive wastes and wastes with high inorganic salt content and/or heavy metals require special evaluation. This operation can create high particulate emissions which require post-combustion control.

**STATUS:** Rotary kiln incinerators are commercially available and are in wide use.

**SOURCES:** S.D. Myers, Inc.  
American Industrial Waste of  
ENCISO, Inc., (mobile)  
Exceltech, Inc.  
Coen Co.  
International Waste Energy  
Systems  
Thermal, Inc.  
Lurgi Corp.  
Komline Sanderson  
International Waste Energy System  
Winston Technology, Inc., (mobile)  
Volland, U.S.A.  
Von Roll  
DETOXCO Inc.



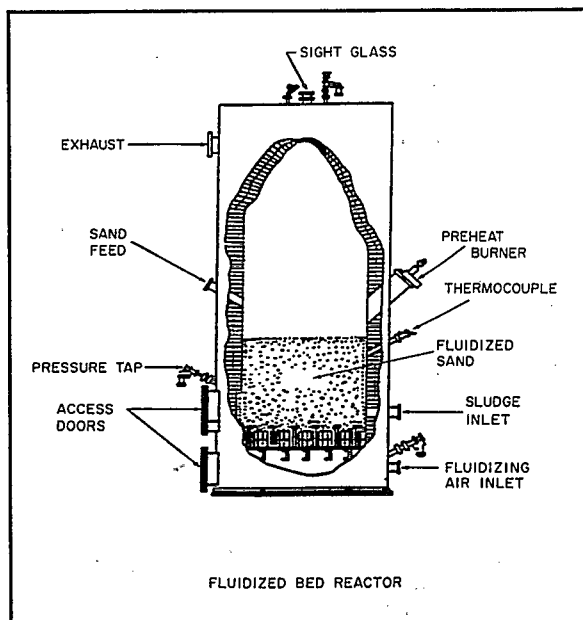
## TECHNOLOGY: Fluidized Bed Incineration

**DESCRIPTION:** Fluidized bed incinerators utilize a very turbulent bed of inert granular material (usually sand) to improve the transfer of heat to the waste streams to be incinerated. Air is blown through the granular bed materials until they are "suspended" and able to move and mix in a manner similar to a fluid, i.e., they are "fluidized." In this manner, the heated bed particles come in intimate contact with the wastes being burned. The process requires that the waste be fed into multiple injection ports for successful treatment. Advantages of this technology include excellent heat transfer to the material being incinerated and a long residence time. An off-shoot of this technology is a circulating bed combustor.

**APPLICABILITY/LIMITATION:** Fluidized beds require frequent attention for maintenance and cleaning purposes. This treatment is ideal for slurries and sludges but not for bulky or viscous wastes. The waste particles should be of a certain size and be homogeneous. Wastes must have a low sodium content and a low heavy metal content. Some refractory wastes may not be fully destroyed since these units operate at low combustion temperatures (750° to 1000° C).

**STATUS:** Fluidized bed incineration is presently available in a demonstration-scale unit for hazardous waste. They have been used to incinerate municipal wastewater treatment plant sludge, oil refinery waste, some pharmaceutical wastes, and some chemical wastes including phenolic waste, and methyl methacrylate. Heat recovery is possible.

**SOURCES:** Lurgi Corp.  
G.A. Technologies  
Waste-Tech Services, Inc.  
Dorr-Oliver  
Combustion Power  
Niro Atomizer



## TECHNOLOGY: Pyrolysis

**DESCRIPTION:** Pyrolysis is the chemical decomposition of waste brought about by heating the material in the absence of oxygen. The system involves the use of two combustive chambers. In the primary chamber the wastes are heated, separating the volatile components (combustible gases, water vapor, etc.) from the nonvolatile char and ash (metals and salts). In the secondary chamber (afterburner or fume incinerator) volatile components are burned under the proper air, temperature, time and turbulence to destroy any remaining hazardous components. Temperature in the pyrolysis section is controlled by the addition of auxiliary fuel. There are two ways to heat the material; the first is by direct heating where the material comes in contact with hot combustion gases from a burner or incinerator. The resulting off-gas is a combination of the combustion gases and the volatiles from the waste. The second method is by indirect heating by an electric resistance heating element or an external burner with its exhaust gases directly vented to the atmosphere. This approach allows product recovery, rather than incineration, from the gaseous stream leaving the primary chamber without contamination or dilution by the burner flue gases. Indirect heating is more complex and expensive than direct heating. Pyrolysis can be designed for batch burning of drummed or containerized material

or continuous processing of flowable solids and liquids. The hot combustion gases from the secondary chamber can be passed through a boiler to recover energy. Liquid wastes can be injected simultaneously into the secondary chamber during the pyrolyzing of waste in the primary chamber.

**APPLICABILITY/LIMITATION:** This technology is used to treat viscous liquids, sludges, solids, high-ash material, salts and metals or halogenated waste that are not conducive to conventional incineration, wastes that are stored in containers or which contain volatile metals or recoverable residues. The limitations are that it requires auxiliary fuel, currently has small capacity of waste input and metals and salts in the residue can be leachable, thus, requiring residue disposal as a hazardous waste.

**STATUS:** Commercially available, batch and continuous pyrolysis processes exist.

**SOURCES:** Midland-Ross Corp.  
American Energy Corp.  
Econo Therm Energy Systems  
Lurgi Corp.  
J.M. Huber Corp.  
Shirco Infrared Systems, Inc.  
Spencer Boiler and Engineering, Inc.

## **TECHNOLOGY: Wet Air Oxidation**

**DESCRIPTION:** Wet air oxidation uses elevated temperature and pressure to oxidize dissolved or finely divided organics. The oxidation products usually remain dissolved or suspended in the liquid. The off-gas is low in nitrogen oxides, sulfur oxides and particulates. Off-gas treatment may be necessary to control hydrocarbon emissions. The advantages are, it is thermally self sustaining, accepts waste with organic concentrations ranging between those considered ideal for either biological treatment or incineration, detoxifies priority pollutants and the products of oxidation stay in the liquid phase. Wet air oxidation is particularly well suited for treating organic compounds in aqueous waste streams that are too dilute (less than 5 percent organics) to treat economically by incineration. Oxidation of the organic compounds occurs when the aqueous solution is heated to about 300° C and 137 atm in the presence of compressed air. Typically, 80 percent of the organic substances will be completely oxidized. The

system can accommodate some partially halogenated compounds, but highly-chlorinated species, such as PCBs, are too stable for complete destruction without the addition of catalysts or the use of very high pressure and temperature.

**APPLICABILITY/LIMITATION:** This process is used to treat aqueous waste streams with less than 5 percent organics and with some pesticides, phenolics, organic sulfur and cyanide wastewaters. It is not recommended for aromatic halogenated organics, inorganics or for treating large volumes of waste. This technology is not appropriate for solids or viscous liquids.

**STATUS:** Available at commercial scale

**SOURCES:** Zimpro Inc.  
Modar Inc.  
Vertox Treatment Systems

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## **TECHNOLOGY: Industrial Boilers**

**DESCRIPTION:** Some industrial boilers can use limited amounts and types of wastes as supplemental fuels so that the wastes are destroyed while recovering the available heat from the waste. Hazardous waste is used as supplementary fuel to coal, oil or natural gas in fire-tube and water-tube industrial boilers. Hazardous waste fuel (generally limited to liquid waste) can be fed into a boiler with the primary fuel or it can be fed separately into the furnace. If a facility is burning its own wastes as fuel, it can control "fuel quality" to a great extent. If wastes are imported for use as fuel, then it is common to blend incoming wastes to an "optimum" supplemental fuel for that facility's boilers.

**APPLICABILITY/LIMITATION:** Chlorine and sulfur must be limited in Hazardous Waste Fuel (HWF) to minimize corrosion of boiler materials

of construction and to avoid increases in HCl and sulfur oxide air emissions. Solid hazardous wastes such as contaminated soil are not applicable for use as HWF in boilers. Industrial boilers are particularly useful for the disposal of hazardous waste generated on site.

**STATUS:** Only a small fraction of the nation's 23,000 fossil-fueled boilers are in use burning hazardous waste as fuel.

**SOURCES:** Various manufacturers, may be packaged units or field constructed

## **TECHNOLOGY: Industrial Kilns (Cement, Lime, Aggregate, Clay)**

**DESCRIPTION:** Industrial kilns are used to incinerate liquid wastes while recovering heat value. The system consists of rotary kilns constructed of steel casings lined with refractory brick. These kilns are much longer than rotary kiln incinerators and have much longer retention times. Blended feed material (a waste/air mixture) is fed into the hot end of the kiln as a supplement to the primary fuel (coal, gas, or oil). Kiln temperatures are about 3000° F for cement and lime kilns and less than 2000° F for aggregate and clay drying kilns. Organics are destroyed while the ash is assimilated into the kiln product. Waste blending is necessary to obtain desired fuel characteristics to control product quality. The kiln should contain a precipitator or baghouse in order to remove suspended particulates in the flue gases.

**APPLICABILITY/LIMITATION:** Kilns have generally been limited to liquid waste. Heavy metals,

ash, chlorine and sulfur content of waste fuel must be controlled to prevent kiln operating and product quality problems. Contaminated soils are not good candidates for treatment in industrial kilns because of concern for product quality. The system should be equipped with air pollution control devices.

**STATUS:** The use of hazardous waste as a fuel in kilns is becoming more widespread. At least 15 cement kilns and at least six aggregate kilns are now burning hazardous waste fuel as supplemental fuels in the U.S. This technology can be considered conventional and well demonstrated.

**SOURCES:** SYSTECH Corp.  
PATCHEM - Waste Management  
McKesson Envirosystems Co.

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## **TECHNOLOGY: Blast Furnaces (Iron and Steel)**

**DESCRIPTION:** Blast furnace temperatures may reach up to 3400° F and are generally above 3000° F. High heat content hazardous wastes can be used to supplement the fuel requirements for blast furnaces. A blast furnace produces molten iron from iron ore and other iron bearing feed materials. Iron ore, carbon (coke) and limestone are fed to the top of the furnace, and iron product and slag are removed in different layers from the bottom. Hazardous wastes used as fuels can be injected above the slag layer.

**APPLICABILITY/LIMITATION:** The composition (trace elements) of the waste must be controlled to avoid product quality problems. Waste oils were fired in a blast furnace in HWERL test programs. Some concerns have been expressed that the reducing atmosphere in a blast furnace could result in reduced DREs.

**STATUS:** There are less than 80 blast furnaces currently operating in the U.S. The authors are aware of none that are currently burning hazardous waste as fuel.

**SOURCES:** N/A

## TECHNOLOGY: Infrared Incineration

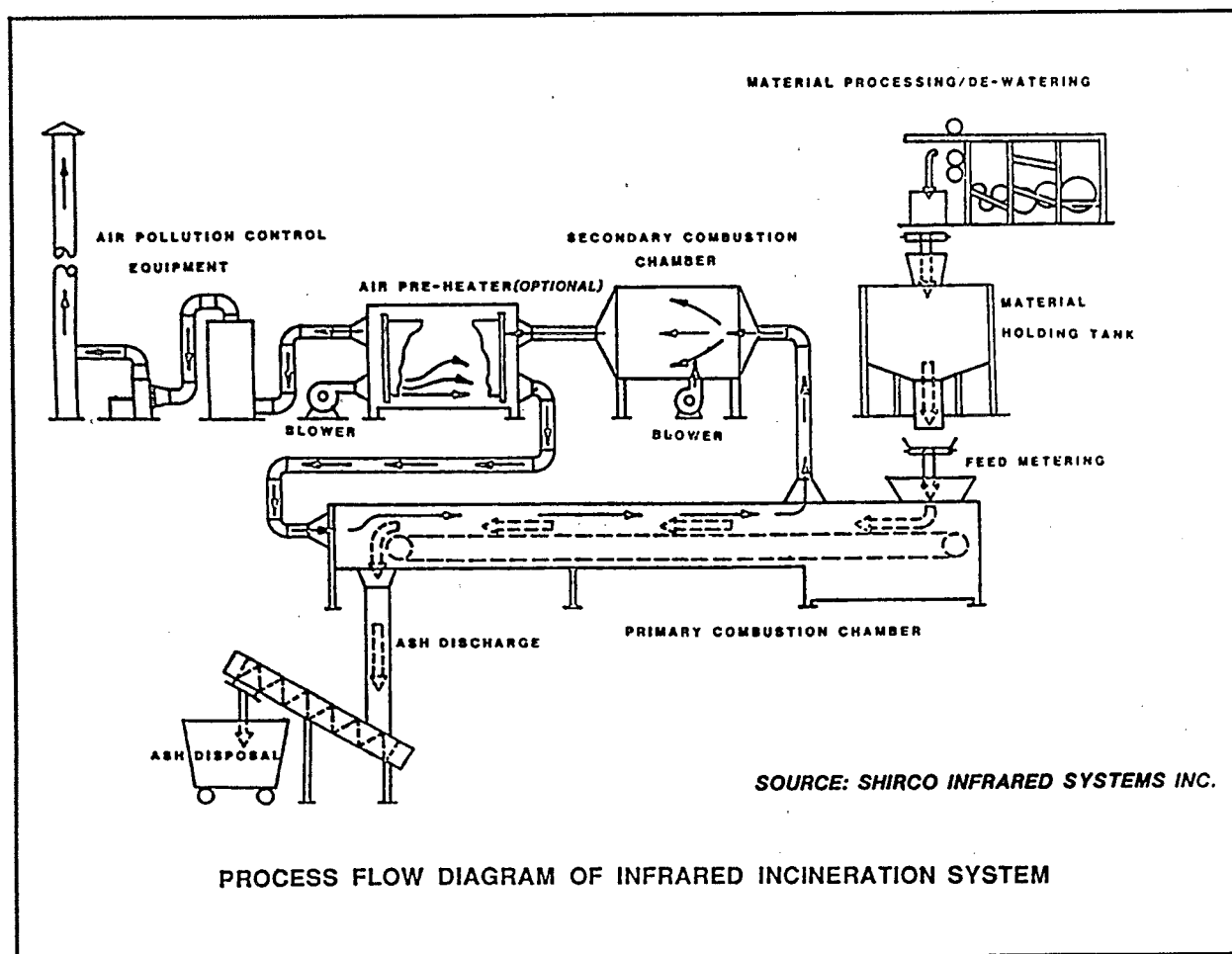
**DESCRIPTION:** Infrared radiators can be used as the heat source in the destruction of hazardous waste. This system is made up of a primary chamber consisting of a rectangular carbon steel box lined with layers of a light-weight, ceramic fiber blanket. Infrared energy is provided by silicon carbide resistance heating elements. The material to be processed is conveyed through the furnace on a woven wire belt. Solids are pyrolyzed on the hearth. Sufficient air (or oxygen) is introduced to fully combust the off-gases. When the waste reaches the discharge end of the furnace it drops off the belt into a hopper. The advantages include a quiescent combustion zone which results in low particulate emission, reduced gaseous pollutant emissions, low fossil fuel usage, and up to 50 percent operational turndown capacity. This system al-

lows a high degree of control and long-residence times for solids are achievable.

**APPLICABILITY/LIMITATION:** This technology is used primarily to treat solids (not larger than a specified size) sludges and contaminated soils, but liquid or gaseous injection systems are available.

**STATUS:** Operational units exist at several locations, mobile units are under construction and units are presently under evaluation in the SITE Program.

**SOURCES:** Shirco Infrared Systems  
Haztech  
Maecorp Inc.  
Reidel Environmental Services



## **TECHNOLOGY: Circulating Bed Combustor**

**DESCRIPTION:** The circulating bed combustor is designed to be an improvement over conventional fluidized beds. The system operates at higher velocities and finer sorbents than fluidized bed systems. This permits a unit that is more compact and easier to feed. The unit also produces lower emissions and uses less sorbent materials than the fluidized bed systems. No off-gas scrubber is necessary in the circulating bed combustor and heat can be recovered as an added benefit. The key to the high efficiency of the circulating bed combustor is the high turbulence that is achieved within the combustor. This feature allows efficient destruction of all types of halogenated hydrocarbons including PCBs and other aromatics at temperatures less than 850° C (Freeman, 1985). Acid gases are captured within the combustion chamber by limestone in the bed. A baghouse is needed for particulate control. Compounds containing high levels of phosphorus, sulfur, cyanide, etc. can be processed with low emissions of NO<sub>x</sub>, CO and acid gases. In addition to the turbulence, a large combustion zone with uni-

form and lower temperature throughout also contributes to high efficiency. The circulating bed combustor also features longer residence time of the combustibles and sorbents in the combustion zone.

**APPLICABILITY/LIMITATION:** The system is capable of treating solids, sludges, slurries and liquids. The high degree of turbulence and mixing ensures treatment of a wide variety of wastes. The waste however, must be fairly homogeneous in composition when fed to the combustor, since it is usually introduced at only one location. An additional benefit of the circulating bed combustor is the possibility of heat recovery. The combustion chamber can be of "waterwall" construction.

**STATUS:** Ready for full-scale testing. Unit is in RCRA permit process.

**SOURCES:** G. A. Technologies  
Riley Stoker  
Keeler Dorr-Oliver

## **TECHNOLOGY: Supercritical Water Oxidation**

**DESCRIPTION:** The supercritical water oxidation process is basically a high temperature, high pressure wet air oxidation. The unique properties of water above 500° C (supercritical region) causes it to act as an excellent nonpolar solvent for nearly all organic materials. Aqueous solutions or slurries (organic content greater than 5 percent) are mixed with high pressure oxygen (3200 to 3600 psi or greater than 218 atm), to chemically oxidize waste in less than one minute at greater than 99.99 percent efficiency.

Two processing approaches have been evaluated, an above ground pressure vessel reactor (Modar) and the use of an 8000 to 10,000 ft deep well as a reactor vessel (Vertox). The supercritical water process is best suited for large volume (200 to 1000 gpm) dilute (in the range of 1 to 10,000 mg/l COD) aqueous wastes that are of a volatile nature and that have a sufficiently high heat content to sustain the process. In many applications, high Btu, nonhazardous waste can be mixed with low Btu hazardous waste to pro-

vide the heat energy needed to make the process self sustaining. Emissions/residues include gaseous effluent (nitrogen and carbon dioxide), precipitate of inorganic salts and the liquid containing only soluble inorganic acids and salts. The advantages are rapid oxidation rates, complete oxidation of organics, efficient removal of inorganics and no off-gas processing is required.

**APPLICABILITY/LIMITATION:** Supercritical water oxidation is used to treat aqueous organic solutions/slurries and mixed organic/inorganic waste, which are pumpable. Sophisticated equipment and operations and long term continuous operations have not been demonstrated, thereby limiting its use.

**STATUS:** Demonstration of use with municipal sewage sludge completed in 1985

**SOURCES:** Vertox Corporation  
Modar Inc.

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## **TECHNOLOGY: Advanced Electric Reactor**

**DESCRIPTION:** Advanced electric reactors use electrically heated fluid walls to pyrolyze waste contaminants. The resulting thermal radiation causes pyrolysis of the organic constituents in the waste feed. At these high temperatures inorganic compounds melt and are fused into vitreous solids. Most metal salts are soluble in these molten glasses and can thus become bound in a solid matrix (vitrified beads). Following pyrolysis in the reactor, granular solids and gaseous reactor emissions are directed to a post reactor zone, where radiant cooling occurs. The advantages are that it is transportable, has a high treatment efficiency and emissions are low.

**APPLICABILITY/LIMITATION:** This process is used to treat organics or inorganics, in solid,

liquid or gaseous form (solid or liquid may require pretreatment) and for PCB or dioxin contaminated soils. It is limited to treating solids less than 35 US mesh and liquids atomized to less than 1500 micron droplets. A post treatment process may be needed in order to remove products of incomplete combustion from the emissions.

**STATUS:** Demonstrated on a pilot scale

**SOURCES:** Thagard Research Corp.  
J. M. Huber Construction



## **TECHNOLOGY: Molten Salt Destruction**

**DESCRIPTION:** Molten salt combustion is a method of burning organic material while, at the same time, sorbing the objectionable by-products of that combustion from the effluent gas stream. This process of simultaneous combustion and sorption is accomplished by mixing the air and waste into a pool of molten sodium carbonate. The melt is maintained at temperatures between 1500 to 2000° F, causing the hydrocarbons of the organic matter to be oxidized to carbon dioxide and water, while elements such as phosphorus, sulfur, arsenic and the halogens react with the sodium carbonate. These by-products are retained in the melt as inorganic salts and eventually build up and must be removed in order that the molten bed remain fluid and retain its ability to absorb acidic gases. An ash concentration in the melt of up to approximately 20 percent by weight is acceptable.

**APPLICABILITY/LIMITATION:** Molten salt can be used to treat low ash or high chlorine content wastes. Low water content is required and the molten salt produced can be corrosive. The neutralization of acid gases results in the formation of other salts that can change the fluidity of the bed and hence require frequent replacement of the material. Used salts must be landfilled.

**STATUS:** Developmental, pilot-scale unit available

**SOURCES:** Rockwell International

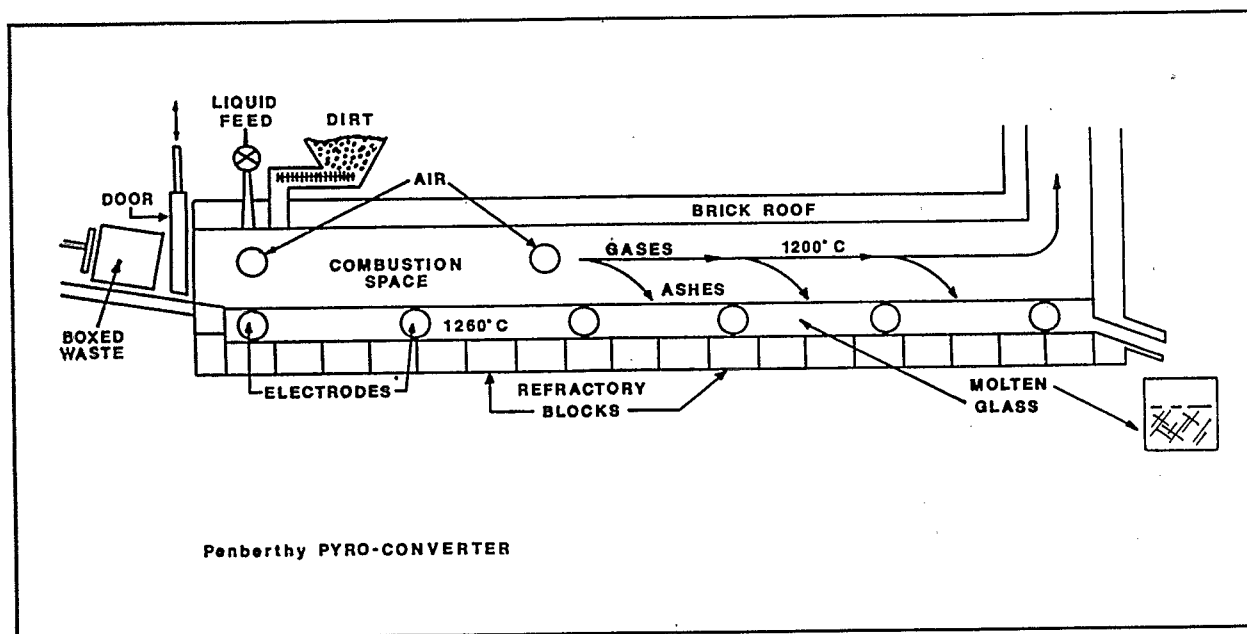
## TECHNOLOGY: Molten Glass

**DESCRIPTION:** This technology uses a pool of molten glass as the heat transfer mechanism to destroy organics and to capture ash and inorganics. The emissions include acid gas and any particulates while all residues are contained in the glass. The advantages include significant volume reduction, most wastes are treatable and the residual is stabilized, nonbreaking glass. The process is based on existing glass making technology.

**APPLICABILITY/LIMITATION:** Molten glass can be used to treat any solid or liquid such as plastics, asphalts, PCB or pesticides. Sodium sulfates greater than 1 percent of the final glass may pose a problem. It is inappropriate for soils or high ash waste and it requires additional treatment for off-gas.

**STATUS:** The process is commercially available for uses other than hazardous waste incineration

**SOURCES:** Penberthy Electromelt International Inc.  
Battelle-Northwest  
Westinghouse Electric Corp.



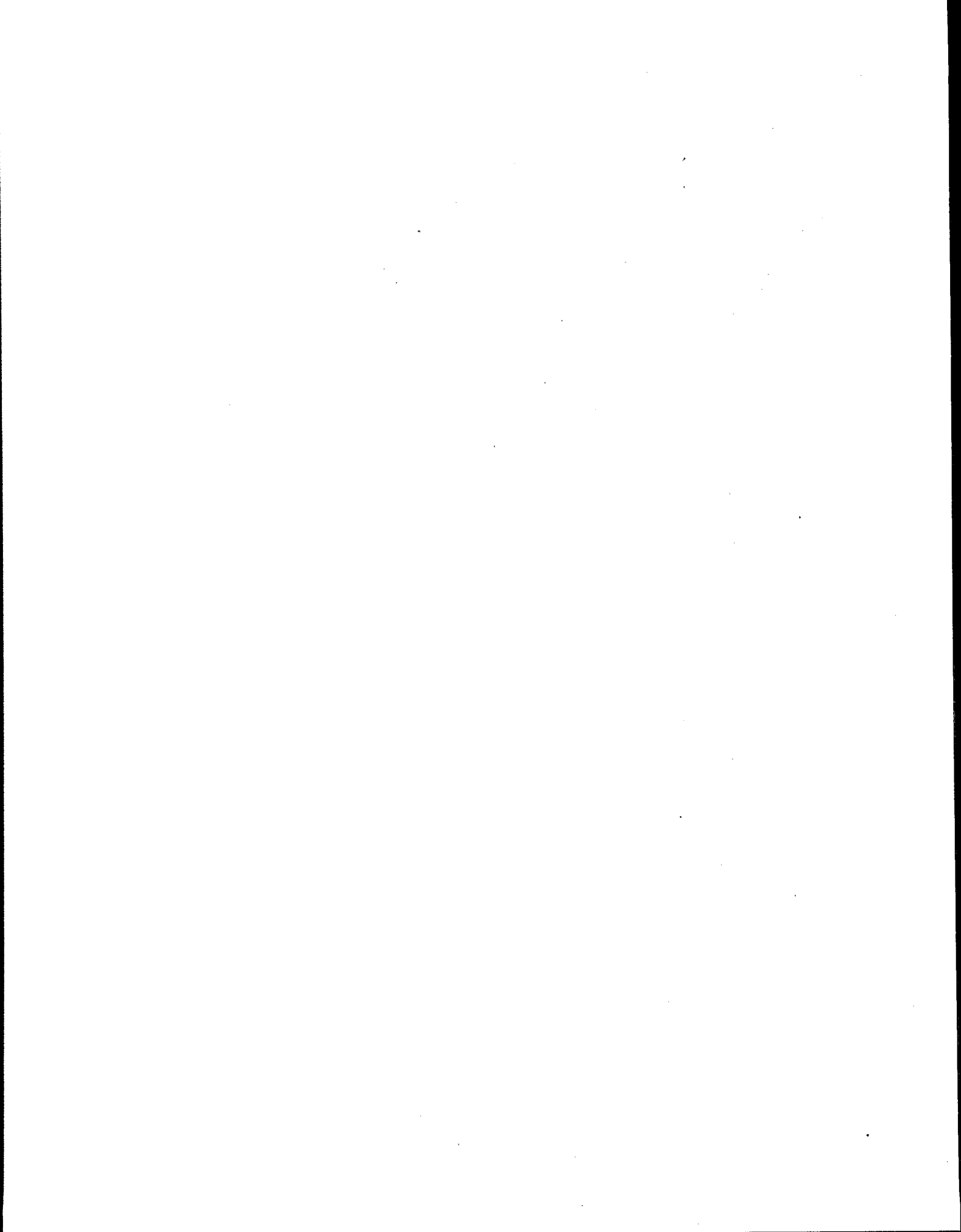
## **TECHNOLOGY: Plasma Torch**

**DESCRIPTION:** The plasma arc process functions by contacting the waste feed with a gas which has been energized into its plasma state by an electrical discharge. The plasma torch acts as one electrode and the hearth at the bottom of the reactor acts as the second electrode. The discharge of electricity between the two electrodes causes the centerline temperatures in the plasma to reach 9000° F. A small amount of gas is introduced into the centerline region and is ionized. The ionized gas molecules transfer energy to the waste to cause pyrolysis of the waste. Since the process is pyrolytic the scale of the equipment is small considering the high throughput rates. This characteristic makes it potentially attractive for use as a mobile unit. Gaseous emissions (mostly H<sub>2</sub>, CO), acid gases in the scrubber and ash components in scrubber water are the residuals. The system's advantages are that it can destroy refractory compounds and typically the process has a very short on/off cycle.

**APPLICABILITY/LIMITATION:** This process is applicable to liquid (pumpable) organic wastes and finely divided, fluidizable sludges. It may be particularly applicable to the processing of liquid wastes with a high chlorine, pesticide, PCB or dioxin content. Sludges must be capable of being fluidized by the addition of a liquid. Waste streams must be free of (or preprocessed to remove) solids, which prevent satisfactory atomization.

**STATUS:** The application of plasma arc technology to hazardous waste treatment is hindered by a lack of operating experience. At this time, the only operating plasma arc system that is beyond the research and development stage is a pilot-scale mobile unit capable of 1 gal/min. of waste. Westinghouse is developing this mobile unit for the SITE Program.

**VENDORS:** Westinghouse Electric Corp.  
Arc Technologies



## **FIXATION/STABILIZATION PROCESSES**

The intent of these processes is to immobilize the toxic and hazardous constituents in the waste. This can be done by changing the constituents into immobile (insoluble) forms, binding them in an immobile, insoluble matrix and/or binding them in a matrix which minimizes the material surface exposed to solvent exposure. Each of the processes described herein accomplishes immobilization by one or more such methods. Often the immobilized product has structural strength sufficient to help protect itself from future fracturing (and concomitant exposure of additional "leachable" surfaces). Most of these processes are proprietary.

### **Important Fixation/Stabilization Treatment Data Needs**

<b>Data Need</b>	<b>Purpose</b>
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The data needed is generally the same as that for both physical and chemical treatment processes.

## **TECHNOLOGY: Lime-Based Pozzolan Processes**

**DESCRIPTION:** This technology treats wastes and contaminated soils by the addition of large amounts of siliceous materials combined with a setting agent such as lime, cement or gypsum. Such treatment results in a dewatered stabilized solidified product.

**APPLICABILITY/LIMITATION:** This stabilization/solidification process is used for sludges and contaminated soils. Contaminants can include metals, waste oils, and solvents. Materials such as borates, sulfates, and carbohydrates interfere with the process. Long-term stability and

resistance to leaching is good for some wastes but is unknown for others.

**STATUS:** Commercially available

**SOURCES:** Different silicate processes available

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## **TECHNOLOGY: Portland Cement Pozzolan Process**

**DESCRIPTION:** This treatment is a minor variant of the lime pozzolan process. This stabilization treatment mixes the waste with portland cement to incorporate the waste into the cement matrices.

**APPLICABILITY/LIMITATION:** This process is effective for metal cations, latex and solid plastic wastes. Large amounts of dissolved sulfate salts or metallic anions such as arsenate and borates will hamper solidification. Organic matter, lignite, silt or clay in the wastes will increase setting time.

**STATUS:** Commercially available

**SOURCES:** Aerojet Energy Conversion Co.  
ATCOR, Inc.  
Chem-Nuclear System, Inc.  
Delaware Custom Materials  
Energy, Inc.  
General Electric Co.  
Hittman Nuclear and Development  
Co.  
Stock Equipment Co.  
Todd Research and Technical Div.  
United Nuclear Industries  
Westinghouse Electric Co.

## TECHNOLOGY: Sorption

**DESCRIPTION:** Contaminants are bound up in pozzolan-type matrices by physical sorption or chemisorption yielding a stabilized material which is easier to handle. Liquid immobilization depends on added ingredients. This process results in high concentrations of contaminants at the surface of the material and contaminants may leach. The treated material is permeable.

**APPLICABILITY/LIMITATION:** The process is suitable for organics and inorganics. Advantages to this technology include the fact that raw materials are plentiful and inexpensive, waste handling is improved, minimal pretreatment is required and the product's bearing

strength is adequate for landfill disposal. Disadvantages include the fact that large volumes of additives are required (albeit they are plentiful and cheap) so that waste volumes to be disposed are greatly increased. Furthermore, leachate control is highly variable, free water may be released under high pressure and there is temperature sensitivity.

**STATUS:** In common use for treatment of metal sludges removed from aqueous waste streams

**SOURCES:** Chemical Waste Management  
TRICIL Environmental

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## TECHNOLOGY: Vitrification

**DESCRIPTION:** Vitrification is a process whereby hazardous wastes are converted into a glassy substance utilizing very high temperatures. The process is carried out by inserting large electrodes into contaminated soils containing significant levels of silicates. Graphite on the surface connects the electrodes to the soil. High current of electricity passes through the electrodes and graphite. The heat causes a melt that gradually works downward through the soil. Some contaminant organics are volatilized and escape from the soil surface and must be collected by a vacuum system. Inorganic and some organics are trapped in the melt, which, as it cools, becomes a form of obsidian or very strong glass. When the melt is cooled, it forms a stable noncrystalline solid.

**APPLICABILITY/LIMITATION:** Vitrification was originally tested as a means of solidification/immobilization of low level radioactive metals. It may also be useful for forming barrier walls. This latter use needs testing and evaluation to determine how uniform the wall would be and stability of the material over a period of time.

**STATUS:** Demonstrated on a field scale

**SOURCES:** Battelle Northwest

## **TECHNOLOGY: Asphalt-Based (Thermoplastic) Microencapsulation**

**DESCRIPTION:** This technology involves the mixing of heated dried waste within either an asphalt bitumen, paraffin, or polyethylene matrix, resulting in a stable solid waste mass. The advantages are: waste volume reduction, low permeability, elimination of free liquids, improved handling and good strength.

**APPLICABILITY/LIMITATION:** This method is applicable to hazardous waste that are complex and difficult to treat. Waste that should **not** be treated using this technology are: waste with high-water content, strongly oxidizing contaminants, anhydrous inorganic salts, tetraborates,

iron and aluminum salts, and organics with low molecular weights and high vapor pressures (volatile). The disadvantages include the fact that process equipment and materials can be expensive and there is some potential for air pollution.

**STATUS:** Commercially available

**SOURCES:** Werner A. Pfleiderer  
Aerojet Energy Conversion Co.  
Newport News Industrial Corp.

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## **TECHNOLOGY: Polymerization**

**DESCRIPTION:** Polymerization uses catalysts to convert a monomer or a low-order polymer of a particular compound to a larger chemical multiple of itself. Often, such large polymers have greater chemical, physical and biological stability than the monomers (or dimers or trimers) of the same chemical.

**APPLICABILITY/LIMITATION:** This technology treats organics including aromatics, aliphatics, and oxygenated monomers such as styrene, vinyl chloride, isoprene, and acrylonitrile. It has application to spills of these compounds.

**STATUS:** Has been used on spills

**SOURCES:** Refer to buyer's guides for sources of catalysts



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